Aviation in Norway. Sustainability and social benefit

4th Report.
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1. Summary

The Report

This is the fourth report from the Norwegian aviation industry on the social benefit and climate and environmental impact from aviation. Work on the report was initiated and led by Avinor, and conducted in collaboration with SAS, Norwegian, Widerøe, the Norwegian Confederation of Trade Unions (LO) and the Federation of Norwegian Aviation Industries (NHO Luftfart).

At the time of writing the global community is strongly affected by the coronavirus pandemic. The consequences for air travel are dramatic, but the pandemic has not changed Norwegian aviation's ambition to reduce the greenhouse gas emissions from air travel and aviation infrastructure.

In addition to presenting facts about the social benefits and environmental impact from air travel, and forecasts and emission reduction methods as previous reports have done, this report, for the first time, provides a roadmap towards the 2050 goal of fossil-free aviation. This means that from 2050, on flights in and from Norway, fossil fuels will not be used.

The importance of aviation

The geography and settlement patterns of Norway mean that people living in the country are more dependent on air travel than elsewhere. Aviation is of critical importance for export industries and tourism, and plays an important role for business in general. Aviation also represents a significant employment sector in terms of both of direct and indirect employment (totalling around 60,000 people in Norway). Furthermore, aviation is important for people's welfare, e.g. travel for medical treatment and to maintain contact with family at home and abroad.

Air travel has a dominant market share of travel between Eastern Norway and other regions. Even for short journeys in Southern Norway, the proportion of travel made by plane is high. Along the coast of Western Norway and in Northern Norway, aircraft are used for relatively short distances as the fjords and the mountains make travelling by road time-consuming. For international travel, air travel totally dominates, with the exception of short trips to Nordic countries.

Aviation finances its own infrastructure through airport and air navigation service charges, as well as commercial revenues at airports. Airports with surpluses finance airports with deficits. In 2019, airlines paid over NOK 2.5 billion in climate-related taxes to the state in addition to VAT on fuel and domestic tickets. For airlines, international competition is strong and the margins are low, meaning that it is essential for there to be equality of opportunity in terms of the business conditions in place across countries.

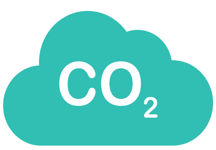
In 2019, just over 11 million round trips were made by Norwegian travellers, and about 6 million round trips by foreigners. Norwegians' travel activity has been fairly stable, with one domestic round trip and one abroad each year, while the volume of trips undertaken by foreigners has greatly increased in recent years due to growth in inbound tourism.

Greenhouse gas emissions and traffic forecasts

There has been an upward trend in traffic at Norwegian airports over time. Domestic traffic has moderately increased over the past 25 years, and emissions have been relatively stable, between 1-1.2 million tonnes of CO_2 equivalents. There has been a dramatic increase in foreign traffic over the same period, and greenhouse gas emissions have also increased. Part of the explanation for this is the increase of direct flights from Norwegian airports and in inbound tourism.

In 2018, greenhouse gas emissions from all domestic civil aviation were 1.2 million tonnes (of which helicopter traffic accounts for around 10 per cent). This was 2.3 per cent of Norway's national emissions. The combined emissions from all sales of jet fuel (including international flights from Norway) were 2.85 million tonnes of CO_2 equivalents in 2018. This corresponds to just over 5.5 per cent of Norway's total emissions.

Due to the coronavirus pandemic, air travel in 2020 has greatly reduced compared with previous years, and there is considerable uncertainty as to when travel restrictions will be lifted and we can once again travel. As the forecasts in this report show, traffic is expected to return to 2019 levels by 2024. From then to 2050, the forecast is 0.7 per cent growth for domestic traffic



5.5%

Air traffic (domestic and foreign) corresponds to around 5.5 per cent of Norway's emissions. Domestic aviation alone accounts for 2.3 per cent.

-50%

Emissions per passenger kilometre have reduced by over 50 per cent in the past 20 years.

one round trip

Norwegians make an average of one domestic round trip and one international round trip by air each year. Traffic growth in recent years is largely due to inbound tourism.

30,000

In 2019, the Norwegian aviation industry directly employed 30,000 people. The positive effects for settlement and business are huge.

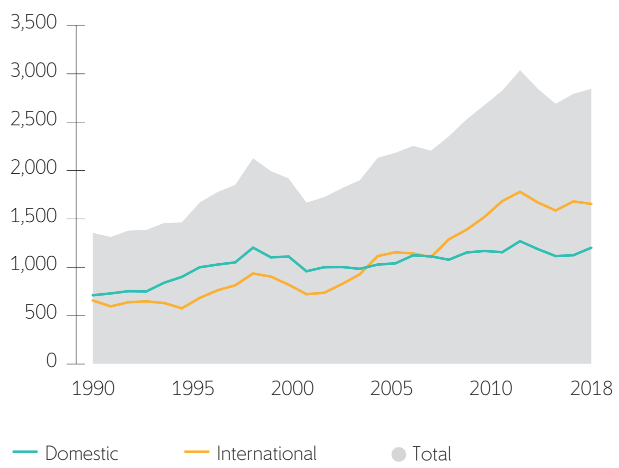


Figure 1: Greenhouse gas emissions from Norwegian civil aviation (incl. helicopters), 1990-2018.

and 2.5 per cent for international traffic. While traffic in Norway and in other OECD countries is starting to level, a significant increase in global air traffic is expected. The strongest growth is forecast to come from emerging economies in Asia, the Middle East, Africa and South America.

Emission reduction measures

The report primarily discusses emission reduction methods for passenger aircraft (not helicopters). There are solutions to reduce emissions from aviation. Fleet replacement and efficiency in airspace are measures currently in operation, and have already resulted in a significant reduction of emissions – emissions per passenger have decreased by more than 50 per cent in the last 20 years. A further reduction of emissions per passenger kilometre is expected, conservatively estimated to be 1.5 per cent per year.

However, due to expected traffic growth, these improvements alone are not enough to reduce overall emissions from air travel.

Sustainable fuels such as biofuels and e-fuels (synthetic fuels)[1] can be used directly in existing aircraft fleets and infrastructure, and is a turnkey solution to reducing greenhouse gas emissions from air travel. Norwegian aviation has been pioneering the adoption of jet biofuels. From 2020, Norway is the first country in the world to have a blending mandate for advanced biofuels in aviation. Norwegian airlines have plans for increased phasing in of sustainable fuels, and the Norwegian authorities have signalled a target of 30 per cent biofuel in aviation by 2030.

By 2030, the first ordinary domestic routes can be electrified, and more routes could be electrified from 2030 onwards. In the short term, these solutions will be particularly relevant for small aircraft on the short-runway operation network, and eventually even for longer distances with larger aircraft.

Hydrogen as an energy carrier could have many uses in aviation – for making fuel that can be used in today's aircraft engines and the associated infrastructure, but also for the production of electricity via fuel cells in electric aircraft, or for direct combustion in jet engines. If Airbus and other players are successful with their plans, hydrogen could make a valuable contribution to fossil-free aviation by 2050.

In order for the aviation industry to achieve the set targets, several solutions must be put into use. Emissions can be reduced in the short term by using sustainable fuels, while new zero- and low-emission technologies must be developed and phased in concurrently.

A roadmap for Norwegian aviation towards 2050

This roadmap is the result of a joint process between Avinor, Widerøe, SAS, Norwegian, NHO Luftfart and LO. The roadmap plots a course for aviation up to 2050. Norwegian aviation is committed to be a driving force to achieving the objectives of the Paris Agreement.

Under the Paris Agreement, a large majority of the world's countries have committed to putting measures in place to limit global warming to a maximum of 2°C, preferably 1.5°C. In practice, this means that by 2050, the world must be an almost zero-emission society.

Norwegian airlines have already set ambitious targets. This roadmap signals a clear ambition in which Norwegian aviation aims to be a world leader:

Norwegian aviation will be fossil-free by 2050.

This means that from 2050, on flights in and from Norway, fossil fuels will not be used.

This goal is ambitious, and calls for significant investment and changes across the aviation value chain over the next few decades, together with effective measures from the authorities.

A key prerequisite is the continued development of technology and functioning markets for low emission solutions: more energy-efficient aircraft, competitively priced sustainable fuels, solutions for electrification and hydrogen as an energy carrier. This development is already under way, and there is every reason to expect it to continue. Norwegian aviation relies on technology, markets and policies to work together to achieve the fossil liberties target in 2050.

Aviation is shaped by strong international competition. Measures and initiatives must be modelled so that they promote the further development of climate-friendly technologies while not weakening Norwegian airlines' competitive situation. In an industry such as aviation, measures should be first and foremost international and non-discriminatory in nature.

The roadmap will become more tangible over time as it becomes clearer when new technology will be phased in, and when new types of sustainable fuels certified for aviation become available on a larger scale.

Why?

The climate crisis is one of the greatest challlenges of our time. All of society – including aviation – must reduce greenhouse gas emissions if irreversible climate change is to be prevented.

Fossil-free aviation will be a very competitive mode of transport and a key contributor to the mobility of the future. Air travel is a superior mode of transport for long distances, and on journeys where time is a decisive factor. Air transport plays an important role in business, settlement, exports and tourism, and for Norwegians' mobility in general. Air travel is already characterised by relatively small encroachments on nature and limited noise pollution when compared with other modes of transport.

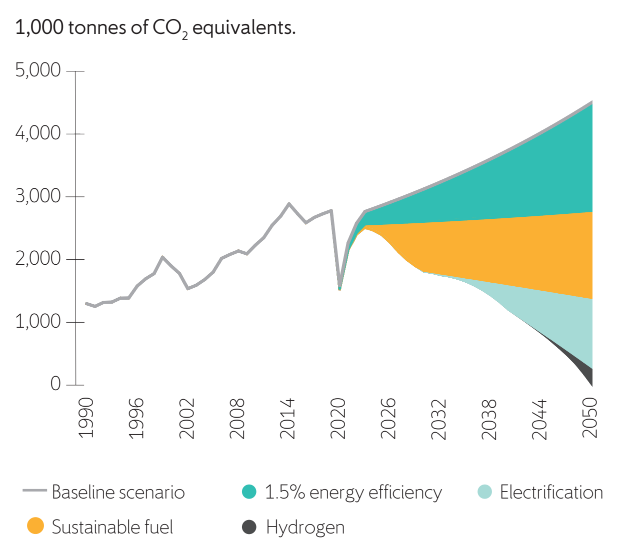


Figure 2: The road towards 2050.

The cost of reducing emissions in aviation is currently high compared to equivalent costs in other parts of society. Aviation safety takes the highest priority, and there are often long and resource-intensive development and certification processes in the industry. However, in the longer term, low-emission solutions can reduce both costs to the environment and the airlines' operational and maintenance costs. Norwegian aviation believes that it can bring significant advantages to society if targeted measures to phase out fossil fuels are initiated now:

- By taking a leading international role in decarbonising aviation through sustainable fuels and electrification, Norway can make an impact on reducing greenhouse gas emissions far beyond its borders
- Norway has a major competitive advantage for value creation and and industry establishment within sustainable fuels, hydrogen and electrification
- A transition to fossil-free aviation will secure jobs in the aviation, export and tourism industries, and for business in general
- Technological development in aviation takes time; a challenging and ambitious decarbonisation effort requires predictability and a long planning horizon

How?

Technological solutions exist. Sustainable fuels, electrified aircraft and hydrogen will, together with efficiency in airspace and technologies that lower emissions from the fleet, enable fossil-free aviation.

Norway is the first country in the world to implement a blending mandate for sustainable jet biofuels for civil aviation, with effect from 2020. The Norwegian parliament has established a target to reach 30 per cent by 2030. Electrification will further reduce the use of fossil fuels, and Avinor and the Norwegian Civil Aviation Authority have prepared a programme proposal for the introduction of electrified aircraft to Norway. A target of fossil-free aviation by 2050 is a confirmation that the industry wants to phase in sustainable fuels and electrified aircraft at an ambitious but realistic pace.

Norwegian aviation will:

- Be a driving force for the development and adoption of zero- and low-emissions solutions
- Phase in sustainable fuels
- Reduce emissions through continued efficiency in airspace, together with optimised planning and operation of flights
- Take the initiative to develop a programme for the production and increased phasing in of sustainable fuels (advanced biofuels and e-fuels)
- Strengthen efforts with communication, incentives and ability for businesses and individual travellers to choose alternatives that are the best for the environment
- Contribute to a good knowledge base about the potential of various low- and zero-emission solutions for the sector
- Regularly report on the achievement of targets, as well as proposing regular benchmarking against other countries where aviation has set ambitious targets (for example, Sweden, Denmark, Finland, the Netherlands and the UK)

Partnership with the government

Norwegian aviation will go to great lengths to achieve the goals set out in this plan, but cannot achieve them alone. In order for Norwegian aviation to contribute to the fulfilment of Norway's climate goals, there needs to be a partnership between the industry and the authorities.

Norwegian aviation proposes:

- The establishment of regular high-level meetings between the authorities and the aviation industry, for example in the form of a dialogue forum, where status, measures and initiatives are discussed with regard to emissions, value creation and the industry's competitive situation
- Significant national and European investment in research and development to bring out competitive technologies that reduce greenhouse gas emissions, including sustainable fuels, electrification and hydrogen
- Predictable framework conditions and secure financing that accelerates the development, production and use of climate-friendly technologies, for example in the form of a fund where taxes the industry currently pay to the state are included
- That Norway works to significantly strengthen international measures at the European and global level, including the EU Emissions Trading System (EU ETS) and the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA).
- That measures that can enable the early introduction of electrified aircraft in line with the "Proposal of a programme for the introduction of electric aircraft in commercial aviation" are phased in
- That the public sector uses its purchasing power to create demand for sustainable fuels
- A transformation to fossil-free aviation that can create jobs throughout Norway; in order to realise the potential for value creation in Norway, there is a need for the government to strengthen the facilitation for the establishment and scaling of Norwegian industry

2. Introduction

This is the fourth report from the Norwegian aviation industry on aviation's social benefit and climate and environmental impact. The three previous reports were published in 2008, 2011 and 2017. The work on this report was initiated and led by Avinor, and carried out in partnership with SAS, Norwegian, Widerøe, LO and NHO Luftfart.

In working on the report, a reference group consisting of representatives from ZERO, Bellona, Friends of the Earth Norway, Rainforest Foundation Norway, Future in our hands (Framtiden i våre hender) and Virke Reiseliv have given constructive and useful input. However, the reference group has no responsibility for the results or the conclusions of the report.

This report was written while the global community was severely impacted by the coronavirus pandemic that seriously took hold in February and March 2020. Travel restrictions that were introduced have led to a dramatic decline in air travel. This has affected the aviation industry to such a strong degree that no one can foresee what the consequences for the industry will be, in both the short and the long term. The full economic consequences of the pandemic for the aviation industry remain to be seen, but it has not affected our ambition to reduce greenhouse gas emissions from air travel and aviation infrastructure.

The report is titled "Aviation in Norway. Sustainability and social benefit". The premise of the report is that aviation plays a crucial role in Norwegian transport infrastructure. It is difficult to imagine Norway without aviation. At the same time, greenhouse gas emissions must be reduced if irreversible climate change is to be avoided. As a society, we must reach the goals set out in the Paris Agreement. Norwegian aviation sets out ambitious targets in this report. In order for the targets to be reached, it is necessary that the Norwegian aviation industry has framework conditions that ensure necessary investments can be made. These three elements: the economy, the environment and social benefit must be balanced in such a way that aviation can contribute to sustainable value creation.

The report primarily discusses emission reduction methods for passenger aircraft (not helicopters).

3. Norway is dependent on a good provision of aviation services

Norway is an elongated country with scattered settlements and a location on the outskirts of Europe. This makes us more dependent on air travel than most other countries. In an open and internationally-oriented economy with a large share of oil and gas activity, maritime industries and a growing knowledge industry, a good provision of aviation services, providing good connections, is essential. Many activities will not be able to be carried out without aviation. Air travel is also important for the welfare of people throughout the country. Trips for medical, cultural and sporting activities, and leisure trips to visit family and friends over long distances would be difficult to carry out without a good offer of air travel.

For all parts of the country, it is important to be able to efficiently travel to the regional centres and to Oslo. In Lofoten/Vesterålen, flying ensures efficient round trip travel to Bodø, and in Bodø there are fast and smooth transfer opportunities for further travel to Oslo. Similarly, in Troms and Finnmark there are good connections to Tromsø and Oslo. Through a well-coordinated network of airport and flight routes, the vast majority of people in Northern Norway can take a round trip to Oslo in one day, having a constructive day of meetings in the capital. Air travel is also important for long journeys in Southern Norway. A market share of 60-70% of trips between Oslo/Akershus and Stavanger, Bergen and Trondheim illustrates the importance (see Chapter 6). Along the coast of Western Norway, flights are also used for relatively short distances. Svalbard has daily connections via air to the mainland. This supports Norway's ambition to have a presence on the archipelago, and allows the Svalbard community to operate like the rest of Norway.

Air travel is also vitally important when travelling within Northern Norway due to long distances. Flights also play an important role in healthcare here. On the short-haul routes to Bodø and in Finnmark, 20-30 per cent of the journeys are for healthcare/medical purposes on many stretches to/from the larger hospitals. In addition, ambulance flights and helicopter trips require Avinor to extend opening hours and have good emergency preparedness in order to be able to receive them. There were 31,500 ambulance aircraft trips in 2019.

In 2019, Norwegian aviation employed around 30,000 people. A portion of the employment relates to flight operations (around 13,000). These are employees of airlines, in maintenance, operations, air freight, aircraft fuel and catering. Almost 6,000 people are employed at the airports (tower, ground and terminal services, security). Almost 5,000 are related to commercial activities (merchandising, duty free, hospitality, kiosk, hotel, parking, car rental), and 4,000 in other jobs (cleaning, public employees, public transport).

There is additional indirect employment (sub-contractors, goods and services) and induced effects (consumption related to income generated by direct and indirect consumption). In total, these amount to as much as the direct employment, making the total employment in jobs related to the aviation industry around 60,000 people.

4. Need for sustainable business models

Norwegian aviation will be fossil-free by 2050. This is an ambitious goal. In order to achieve this goal, the measures must be technologically and operationally feasible. But the investments also need to be economically sustainable in order to be implemented and scaled.

Aviation infrastructure is self-financed

Avinor is self-financed and the airport operations are run as a single unit in which the financially-profitable airports finance the financially-unprofitable airports.

The primary sources of income are fees from the airlines and passengers, and income from the rental of space for retail operators, duty-free sales, hospitality, parking, and other passenger services. Avinor also has income from the rental of space to airport hotels and parking facilities.

In a normal year, Avinor pays dividends to the owner (the state under the auspices of the Ministry of Transport).

Norwegian airlines compete in an international market

Aviation in Norway is a part of the internal market of the EU, and is highly competitive. This also applies to the Norwegian internal market, although this is now dominated by national players. Intercontinental flight routes are also becoming more and more competitive, partly as a result of more liberal aviation agreements. Competition in the aviation market is strong, and the economic margins are low. Several European airlines have gone bankrupt, and there is significant consolidation in the industry.

The Norwegian airlines are dependent on equal framework conditions in order to compete with airlines from other countries, and special national environmental regulations or taxes may weaken the Norwegian players' ability to compete in the aviation market. Foreign airlines with higher emissions and lower environmental costs will then be able to offer lower prices and outcompete Norwegian airlines. Within international industry, this effect is often referred to as carbon leakage.

The price of jet fuel at European airports varies, and Norway is in the upper tier. This price difference may result in airlines seeing financial gain in buying more fuel than necessary at the departure airport in order to reduce costs. This is called fuel tankering and leads to increased greenhouse gas emissions[2].

Airlines' financial room for manoeuvre

Aviation is characterised by costly assets and long investment horizons. Airlines' ability to invest in new environmentally-friendly technology is limited by low margins, high financing costs, great unpredictability and high requirements for returns. The investments must therefore be profitable and provide relatively quick returns in order to be implemented and scaled.

For most airlines, it costs tens of billions of kroner to renew an aircraft fleet. New aircraft are more fuel efficient, thereby cutting down on both operating costs and emissions. On the other hand, low margins mean that airlines have to borrow money in order to invest in new environmentally-friendly technology. The cost of financing a new aircraft can be up to ten times higher than an old plane.

5. Flights taken by Norwegians

In 2019, around 17 million round trips were made by air from Norwegian airports. Just over 11 million of these were made by Norwegians, while almost 6 million were made by foreign travellers. On average, every Norwegian takes one international return flight and one domestic return flight per year.

The scale of foreigners' travel has greatly increased due to the strong growth in inbound tourism. Between 2000 and 2019, the annual growth in the number of flights taken by Norwegians was 2.4 per cent. The annual population growth was 1 per cent, while the annual growth for the frequency of travel for Norwegians was 1.4 per cent.

According to Norsk Monitor, a small proportion of the population never travels by plane (around 15 per cent abroad and 20 per cent domestically). The majority take between 1 and 3 round trips abroad by plane each year. There are a few who take more than 10 domestic trips or more than 5 trips abroad.

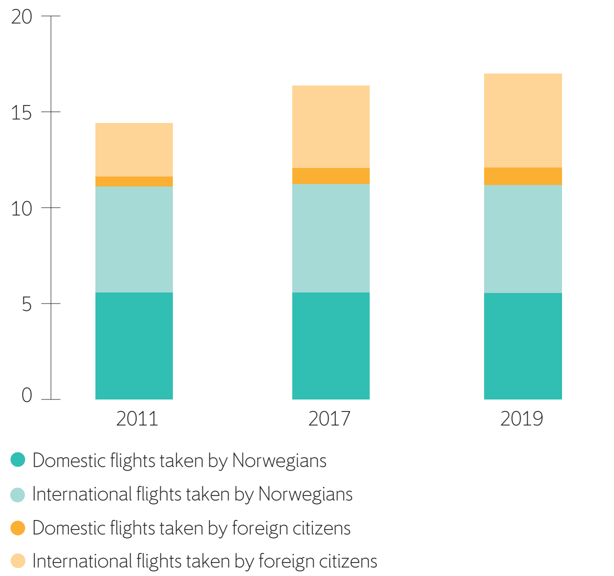


Figure 3: Domestic and international return trips by air by nationality
Source: Air passenger surveys (RVU) 2019.

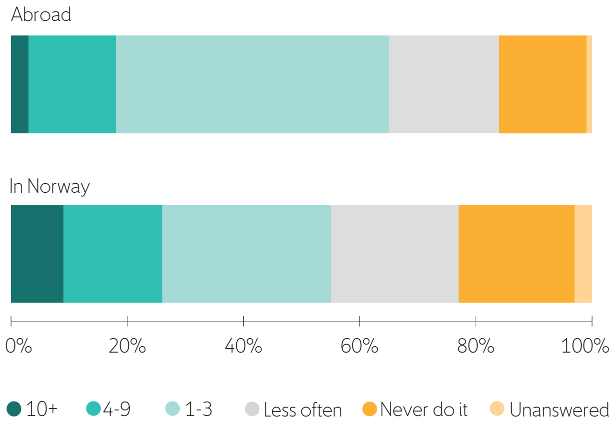


Figure 4: How often did you travel by plane in the last 12 months?
Source: Norsk Monitor 2019.

6. Limited transport alternatives to aviation

Air travel has a dominant market share for travel between Eastern Norway and other parts of the country. If you separate travel to and from Oslo and Akershus, the role of aircraft is even more dominant. On trips to and from Western Norway, Mid-Norway and Northern Norway, air travel has a 60-80 per cent market share. For business travellers, the market share is even higher.

Even for short journeys up to 500km, the proportion made by air is high. One example is the journey between Oslo and Trondheim. It takes an hour to fly, and an hour total to travel to and from the airports. Some additional time must be calculated for security control, walking to and from the departure gate, boarding, etc. Alternatively, travel by car and train takes around 6-7 hours each direction, and requires 7-8 extra hours for a round trip.

Along the coasts of Western Norway and Northern Norway, flights are used for relatively short distances. The fjords and mountains here make land-based transport options time-consuming.

For trips abroad, air travel is dominant. Most trips abroad taken by car, bus or train are short holiday trips to the Nordic countries.

Air travel is crucial for inbound tourism, too. All growth in international traffic after 2013 is due to increased inbound tourism. Many visitors are going further into the country. On domestic routes between Oslo and Northern Norway, 30 per cent of travellers in 2019 were from abroad.

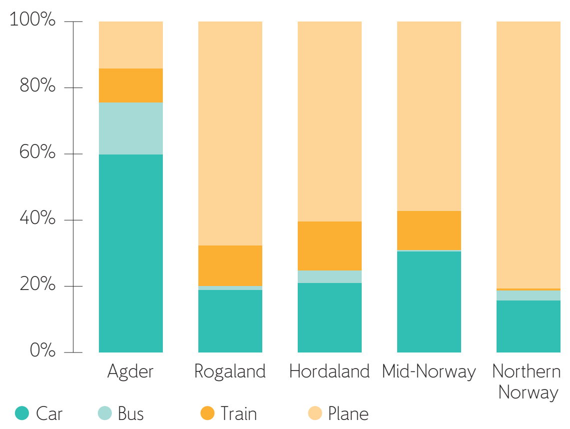
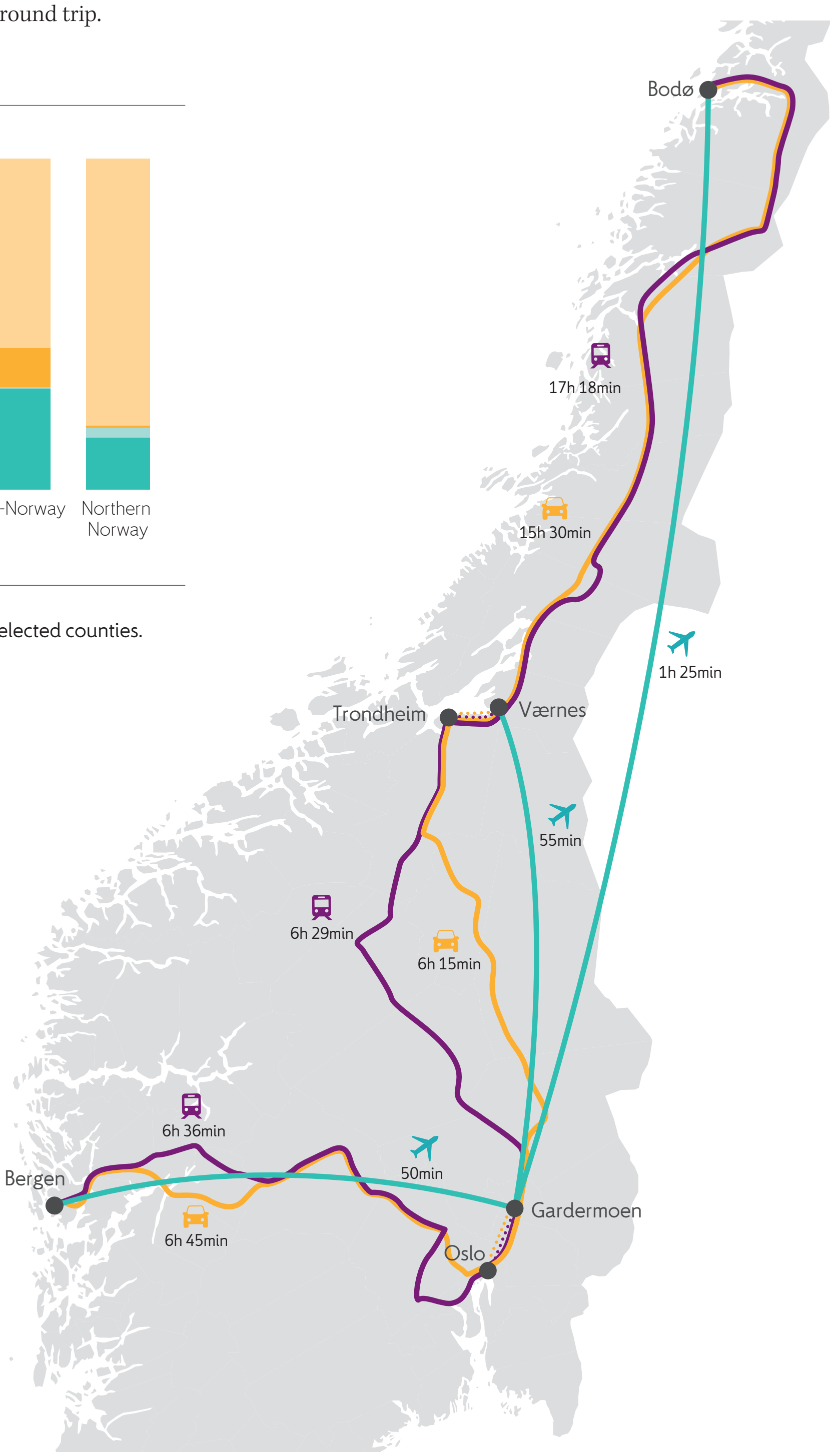


Figure 5: Journeys between Oslo/Akershus and selected counties.
Source: Air passenger surveys (RVU) 2014.



7. Comparison of air travel with other modes of transport

BY ASPIAN VIAK

Transport is a significant contributor to greenhouse gas emissions in today's society. In 2013, passenger transport accounted for 16 per cent of the total greenhouse gas emissions for Norway[3]. In order to compare different transport options and to have good grounds for making decisions for the future, it is important to have a coordinated methodology based on robust data and assumptions for the different modes of transport.

On behalf of Avinor, Asplan Viak has calculated the carbon footprint for passenger transport for selected destinations from Oslo: Bergen, Trondheim and Bodø. Passenger transport by car, train and aircraft was compared. In order to establish the whole picture, calculations have been carried out using life-cycle assessments (LCA), i.e. both direct and indirect emissions are included. The indirect emissions include emissions from infrastructure (construction, operations and maintenance), vehicles (production, operations and maintenance), and fuel/electricity (production and transport/distribution), while the direct emissions are from fuel combustion. The calculations are specific to each route and therefore are not transferable to other routes or for use in comparisons with cars, rail or aviation on a general basis.

Figure 6 shows the results in kg of CO_2 equivalents per person for the three routes. The green part is the direct emissions, and the yellow part is the indirect emissions divided into infrastructure, vehicles and fuel.

For all routes, travel by passenger car gives the highest climate footprint, while train travel emits the lowest emissions by far. The relative difference between passenger car travel and air travel from Oslo to Bergen and Oslo to Trondheim is due to the fact that the distance by car versus the distance by air is greater here.

The different transport options vary greatly on the importance of how much indirect emissions affect total emissions. For passenger cars, indirect emissions account for 36 per cent, for aircraft this is 21 per cent and for diesel and electric trains, this is 39 per cent and 100 per cent respectively. It is the production of fuel that contributes to the indirect emissions for aircraft; vehicles and infrastructure are of minimal importance. This is due to the longevity of aircraft and the many passengers per flight, and the fact that many passengers use the airports. For train travel, it is the infrastructure that has the most impact, while for cars it is the vehicle that gives the most. The major differences here depend on the service life of the vehicles, and the number of passengers the total emissions from the vehicles and the infrastructure should be allocated to.

If you only take direct emissions into account, the picture is completely different – the difference between air and car travel is much smaller. Direct emission from air travel are 89 per cent of direct emissions from car travel on a journey to Bergen, 106 per cent to Trondheim and 76 per cent to Bodø. Electric trains to Bergen and Trondheim give no direct emissions.

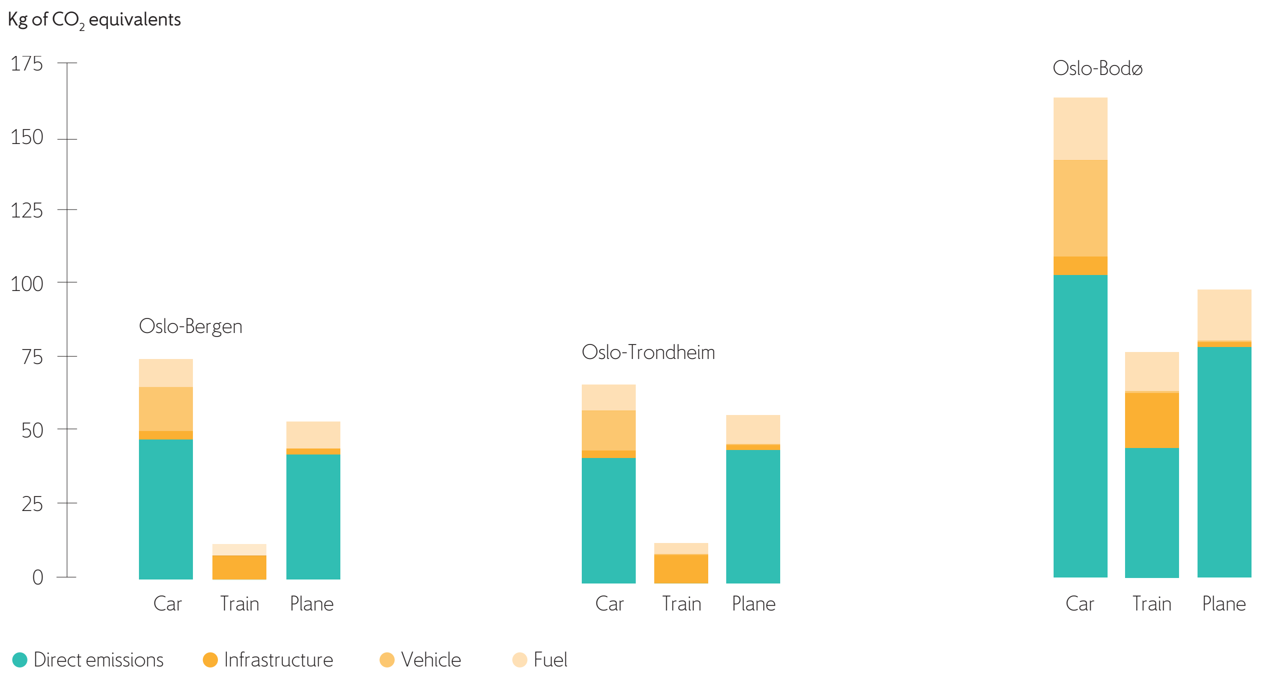


Figure 6: The carbon footprint per person for travel by car, train and air on the three routes – divided into direct and indirect emissions.

Key assumptions in the analyses are[4]:

- The start and end points for the routes are the city centre for the car, the main railway station for the train and the airport for flights
- For passenger cars, calculations are based on the vehicle fleet as of 2019,[5] where both fuel types and Euro classes are taken into account
- For driving, it has been calculated that two people are in the car
- Distribution of electric and petrol for a hybrid is 20/80 per cent on the routes[6]
- Nordic electricity mix (low voltage for electric cars: 126g CO_2e/kWh, high voltage for trains: 109g CO_2e/kWh)
- Statistics from Statistics Norway (SSB) on the number of travellers on trains and aircraft on the different routes

	OSLO – BERGEN	OSLO – TRONDHEIM	OSLO – BODØ	SOURCE
Train	64%	77%	66%	Statistics Norway 2020[7]
Air travel	72%	72%	71%	Statistics Norway 2020[8]

Table 1: Passenger occupancy for the three routes.

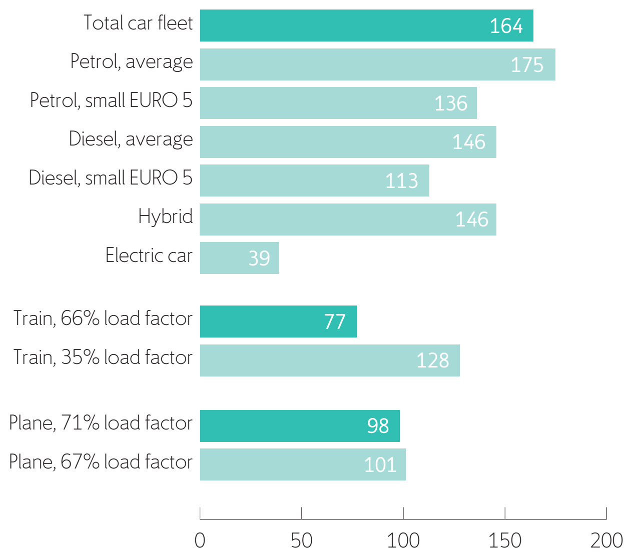


Figure 7: The Oslo–Bodø route: Comparison of travel.

The assumptions that potentially have a major impact on the results are which car/car fleet is used for the basis, the number of passengers per means of transport, the mix of electricity, the service life of vehicles and infrastructure, and factors for allocating the indirect emissions to each passenger. Figure 7 shows the comparison on the route between Oslo and Bodø, with alternative assumptions (the light columns):

- Several options for car types: total car fleet, average number of petrol cars in the fleet, small petrol car Euro class 5, average number of diesel cars in the fleet, small diesel car Euro class 5, hybrid and electric cars (Nordic electricity mix)
- Average national passenger occupancy for trains and aircraft

The results clearly show that there is a large variation in greenhouse gas emissions for different passenger cars, but only full-electric cars give lower emissions than train or air travel. The passenger occupancy of train journeys varies greatly on different routes. In general, you can say that on short routes with frequent departures, there is far smaller occupancy than for longer routes with fewer departures. If the national average for occupancy on trains is used as the basis, greenhouse gas emissions increase to 128kg CO_2equivalents for train travel. For aircraft, there is no significant difference between route-specific occupancy rates and the national average.


SAS
SAS
Scandinavian

8. The polluter pays

Norwegian aviation is subject to several political measures that are directly or indirectly climate-motivated, and Norway is probably the country in the world that has implemented the most measures for aviation. The government's total revenue from climate-related taxes were not insignificant in 2019 (over NOK 2.5 billion), but in 2020 they were greatly reduced due to the reduction in traffic and tax exemptions because of the coronavirus pandemic.

EU Emissions Trading System (EU ETS)

Since 2012, civil aviation in the EU/EEA has been part of the EU ETS in line with emission-intensive industries and energy production. Around 75 per cent of the flights and 90 per cent of the emissions in and from Norway are covered by the EU Emissions Trading System[9]. The ETS is the EU's most important tool in reducing emissions of CO_2, and covers about half of the EU's total greenhouse gas emissions. ETS sets a ceiling on what CO_2 emissions from the sectors subject to allowances can be in total within the EU/EEA. For 2030, the target is that emissions should be cut by at least 43 per cent compared to 2005, and it is now being discussed within the EU whether this target should be increased to 55 per cent.

The reduction in emissions is achieved by reducing allowances each year. The price of the allowances is set in the market, and therefore is dependant on supply and demand. The prices have fluctuated considerably in recent years. In 2019 and 2020, prices have been consistently high, peaking at almost EUR 30 per tonne in September 2020. The long-term trend in the future is expected to be an increased price for allowances (as allowance volume decreases). Higher prices for allowances provide stronger incentives for developing new technologies.

CORSIA

The UN's International Civil Aviation Organisation (ICAO) has set a target of carbon-neutral growth in international aviation from 2020. At the ICAO Assembly in October 2016, the introduction of a quota system was agreed which is known as the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). CORSIA will be a quota system for greenhouse gas emissions from international aviation, and will together with other measures help to achieve this goal. The aviation industry has supported such a Market Based Measure since 2009. The first six-year phase of the mechanism starting from 2021 will be voluntary for participating states. So far, 77 governments, including Norway, have agreed to voluntarily participate in this phase. Air traffic between these states accounts for around 75 per cent of international air traffic. Norway, Europe and the aviation industry organisations are working to strengthen the ambitions of CORSIA.

CO_2 Tax

Norway is one of few countries in the world with a CO_2 tax on domestic aviation. The CO_2 tax was introduced in 1999, and amounts to NOK 1.39 per litre of fuel in 2020, an equivalent to NOK 545 per tonne of CO_2. In 2019, the industry paid a total of NOK 530 million in CO_2 tax. In accordance with international agreements, a CO_2 duty cannot be imposed on international traffic. In NOU 2019:22 Fra statussymbol til allemannseie – norsk luftfart i forandring (From Status Symbol to Public Domain – Norwegian Aviation in Change) among others, it is pointed out that a reduction in emissions from domestic Norwegian aviation caused by specific national policies for EU ETS allowances accordingly, thus not reducing emissions from the EU ETS as a whole. From 2019, however, a new mechanism has been established – the Market Stability Reserve – which can reduce the consequences of such effects. How effective the mechanism is in practice is not yet known.

Air passenger duty

On 1 June 2016, a passenger duty was introduced on flights departing from Norwegian airports, both domestic and international (for domestic duty, a fee is paid in both directions, while for foreign travel, only outbound from Norway). The Ministry of Finance is clear that the air passenger duty is primarily a fiscal tax, but one that can have an effect of reducing emissions, as higher airfares can lead to lower demand. In 2020, air passenger duty has been differentiated. For flights with a final destination in Europe, a lower rate has been imposed (NOK 76.50 per passenger). For flights to other final destinations, a higher rate has been imposed (NOK 204 per passenger). In 2019, the government's income from air passenger duty was in excess of NOK 1.9 billion. For domestic traffic, the tax is also subject to VAT.

NOx tax

A NOx tax duty was introduced in Norway in 2007, with some exceptions, including international shipping and aviation. Domestic aviation is included. In 2008, a NOx fund was established where taxable enterprises can choose to be members. The businesses then pay a payment rate instead to the fund instead of a fee to the state. For aviation, the payment rate as of 2020 is NOK 10.50 per kg. The fund's income finances emission reduction measures for the members.

Blending mandate for advanced jet biofuel

In addition to the emission-related duties listed above, aviation is required from 2020 onwards to blend a proportion of advanced jet biofuels in all fuel refuelled for civil aviation in Norway (both domestic and international). Norway is the first country in the world to impose such a mandate. In 2020, the blending mandate is 0.5 per cent, with a target in the National Transport Plan 2018-2029 of 30 per cent by 2030. The blending mandate's path to 30 per cent mixed biofuels by 2030 has not been defined.

Biofuels cost significantly more than fossil fuels. Airlines and passengers currently bear the additional cost associated with the blending mandate. With blending mandate rates increasing, the cost to airlines and passengers will increase. Norwegian aviation has signalled clear ambitions for increased phasing in of sustainable fuels by 2030. However, there is great uncertainty about future developments for both the supply and demand. For the supply, maturity of technologies, access to suitable biomass, and the establishment of production facilities will be important factors, while the demand will be affected by political decisions in different countries, possibly throughout the EU, on phasing in advanced biofuels. Here you must also look at the developments regarding the phasing in of advanced biofuels for road traffic, as aviation is largely dependent on the same raw materials. This a complex picture, which is part of the reason why Norwegian aviation will initiate a programme for the phasing in of sustainable fuels where such issues will be analysed.

9. Traffic forecasts

The advantage of air travel is that is it faster than all other means of transport. This advantage is particularly important over large distances, and will probably continue to increase in importance as the value of time increases in line with society's productivity increase. In other words, air travel will play an important role in the future, especially for Norway.

The development of aviation largely depends on economic development. With continued economic growth, it is likely that the number of flights will continue to rise. Aviation follows cyclical fluctuations quite closely.

For many years, the growth in aviation was about twice as high as economic growth. New routes and lower prices led to more traffic. As the supply side has been well developed with an extensive network of flights and low prices as a result of decades of competition, the stimulating effect of the supply diminishes over time, improvements on the supply side become increasingly marginal, and aviation will then increase in line with the economy.

There is great uncertainty surrounding the Covid-19 pandemic. When will it be over? And will there be long term effects such as the increased use of home offices, video calls, digital conferences in our work lives, and will holiday habits change with the increased fear of infection?

Furthermore, will the pandemic cause reduced economic activity worldwide, leading to a reduced demand for travel, both at home and abroad? Will new pandemics or other events affect aviation and economic developments in the future?

An analysis from IATA (International Air Transport Association) in July 2020 showed that air traffic may be back at the 2019 level by around 2024.[10] However, this estimate is uncertain.

Similar to the analysis from IATA, this report assumes that air travel in Norway in 2024 will almost be at the 2019 level. Thereafter, 0.7 per cent growth in domestic travel, and 2.5 per cent growth in foreign traffic are predicted towards 2050. This gives a total of 42 million passengers departing from Norway in 2050, or 84 million terminal passengers[11].

Traffic growth has levelled off in Western economies. But strong growth is expected in emerging economies in Asia, the Middle East, Africa and South America. The Airbus 2019 Global Market Forecast shows 5 per cent annual growth in Asia and Africa, compared with about 3 per cent growth in Europe and the United States.

10. Greenhouse gas emissions from aviation

Greenhouse gas emissions from aviation consist of the same greenhouse gases from the burning of fossil fuel in other sectors. The emissions from domestic traffic are regulated through the Kyoto Protocol, and are covered by all countries' national emission obligations accordingly. However, it has not been possible to reach an agreement on how to allocate the emissions from internationa travel. The responsibility for monitoring international emissions has therefore been passed to the aviation agency of the UN (the ICAO), and each country annually reports emissions from internationa traffic to the UN's Framework Convention on Climate Change (UNFCCC). In Norway, the Norwegian Environment Agency and Statistics Norway are responsible for this reporting.

Research shows that because emissions from aviation also occur in the upper atmosphere, additional particles and gases other than those regulated through the Kyoto Protocol can have an effect on the climate. Since 2007, Norwegian aviation has followed the research in this area, and has received assistance from CICERO to present update knowledge about these complex circumstances in all reports that have been published to date.

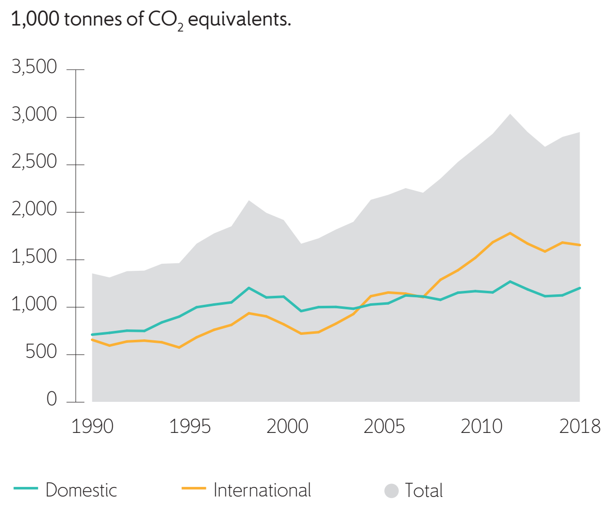


Figure 8: Greenhouse gas emissions from Norwegian civil aviation (incl. helicopters), 1990-2018.

10.1 GREENHOUSE GAS EMISSIONS FROM NORWEGIAN DOMESTIC AND INTERNATIONAL AVIATION

According to the latest official figures from Statistics Norway, greenhouse gas emissions from all domestic civil aviation (including helicopters) in 2018 corresponded to 2.3 per cent of total national emissions (1.2 of a total of 52 million tonnes of CO_2 equivalents). It is these emissions that are covered by the Kyoto Protocol and Norway's climate commitments, and which are reported in the figures from Statistics Norway on greenhouse gas emissions from Norwegian territory. This principle is used in all countries.

Offshore helicopters account for about 10 per cent of Norway's domestic emissions. These emissions are included in the figures above, which include all civil aviation (also offshore/helicopters, but not the Norwegian Armed Forces). However, helicopters are not included in the roadmap and the projections towards the end of the report.

Greenhouse gas emissions from international traffic, i.e. from Norwegian airports with the first destination abroad, amounted to 1.65 million tonnes of CO_2 equivalents in 2018. These emissions are reported annually by the Norwegian Environment Agency and Statistics Norway to the UNFCCC. [12]

Total greenhouse gas emissions from all jet fuel for civil purposes sold at Norwegian airports in 2018 (most recent official figures) equate to just over 5.5 per cent of Norway's total emissions, amounting to 2.85 million tonnes of CO_2 equivalents. Since the mid-1990s, emissions from domestic aviation have been relatively stable, varying between 1 and 1.2 million tonnes per year (around 10 per cent of which from helicopter traffic). Emissions from international traffic has increased. More direct routes from Norway, also intercontinental, help to explain this increase. In recent years, total greenhouse gas emissions from the industry have levelled off.

In 2018, CO_2 emissions from global aviation amounted to 905 million tonnes according to the IATA[13], or about 2.5 per cent of total global CO_2 emissions (37 billion tonnes).

10.2 AVIATION NON-CO_2 CLIMATE IMPACTS

MARIANNE T. LUND, BJØRN H. SAMSET, JAN S. FUGLESTVEDT (CICERO CENTRE FOR CLIMATE RESEARCH)

Global aviation currently (year 2018) constitutes 2.5% of the total human-made CO_2 emissions (including land-use change). However, the total climate impact of the sector involves important non-CO_2 effects. Here we summarize the state-of-the-art scientific knowledge about the impact of aviation emissions on global temperature, building on the comprehensive assessment by Lee et al. (2020).[14]

When including all emissions, global aviation represents around 3.5% of the total warming impact caused by humans to date. This number is slightly lower than the 5% contribution given in previous assessments. This is due to the use of a new metric for comparing different emissions and climate change drivers. Called effective radiative forcing (ERF)[15], this better represents the relationship between the perturbation to the Earth's energy balance and the subsequent surface temperature. Despite strong growth in the aviation sectors over the past 20 years, the relative contribution remains largely constant as other human-made emissions also increase.

Of these 3.5%, CO_2 contributes 1/3, while the non-CO_2 impacts make up the remaining 2/3. Figure 9 summarizes the individual effects (see text box) and their contribution to the sector's climate impact until present-day. Contrail-cirrus has given the largest warming impact, followed by CO_2 and NOx. The direct impact of water vapor emissions and particles is small. The scientific understanding of non-CO_2 aviation impacts has progressed substantially over the last decade. Nevertheless, significant uncertainties in the magnitude of ERF remain. This is especially the case for the indirect effects of particles through modification of clouds. While potentially an important climate impact mechanism, the uncertainty in both sign (warming or cooling) and magnitude is currently too large to provide a best estimate.

Note that the different emissions and mechanisms affect climate at widely varying timescales, which influences their relative importance over time. While contrail-cirrus and NOx-induced ozone increase give strong but short-lived warming, CO_2 accumulates in the atmosphere and becomes dominating in the long term.

To reflect that the total climate impact of aviation is higher than the warming caused by its CO_2 emissions alone, a so-called "multiplier" has been introduced in some applications, such as climate footprint calculators. Due to the range of time scales involved, the value of this multiplier is highly dependent on the method used to convert non-CO_2 effects to CO_2-equivalent emissions and the choice of time horizon. Using the best estimates of ERF from Lee et al. (2020) and a method consistent with e.g., the EU Emission Trading System (that is, using Global Warming Potential on a 100 year time horizon), a multiplier of 1.7 is calculated. This means that the total climate impact of aviation is estimated to be 70% higher the impact of CO_2 alone. The value is consistent with previous assess. Shorter time horizons and alternative methods produce both higher and lower multipliers, ranging from 1.0 to 4.0.

As a response to the well-known challenges related to comparing short- and long-lived climate effects using GWP, an alternative approach was recently introduced. Called GWP*, this new method better represents the impact of the current growth in aviation emissions and reduces the dependence on choice of time horizon. Using GWP*, a multiplier of 3 is calculated - that is, aviation is currently warming the surface three times more than the CO_2 emissions from the sector.

The multiplier is a measure of the global mean impact of global aviation emissions. In contrast, many of the non-CO_2 effects are dependent on where the emission occurs. Hence, the multiplier may not be applicable to aviation in a limited region. An example is domestic Norwegian aviation, where the aircraft fly at lower altitudes than long-haul flights. Research to improve the knowledge about non-CO_2 effects from domestic aviation in Norway is ongoing. [16]

Technological and operational measures to reduce the climate impact of aviation non-CO_2 emissions exist. One much-studied option is re-routing aircraft away from areas where contrail formation is likely to occur. However, this often leads to increased fuel use and higher CO_2 emissions. Recent literature suggests that use of sustainable alternative fuels can reduce not only CO_2 emissions, but also the warming impact of contrail-cirrus.

Climate impact from aircraft emissions

- Water vapour – direct warming effect through increased greenhouse effect
- Contrail cirrus – net warming effect through the formation of contrails and further development of these into cirrus clouds
- NOx – net warming effect from changes in ozone (warming) and reduction in methane (cooling), as well as effects on water vapour and ozone (cooling).
- Sulphur and nitrate particles – direct cooling effect via sunlight reflection
- Soot particles – direct warming effect via sunlight absorption
- Indirect effect of particles on clouds – warming and cooling contributions.

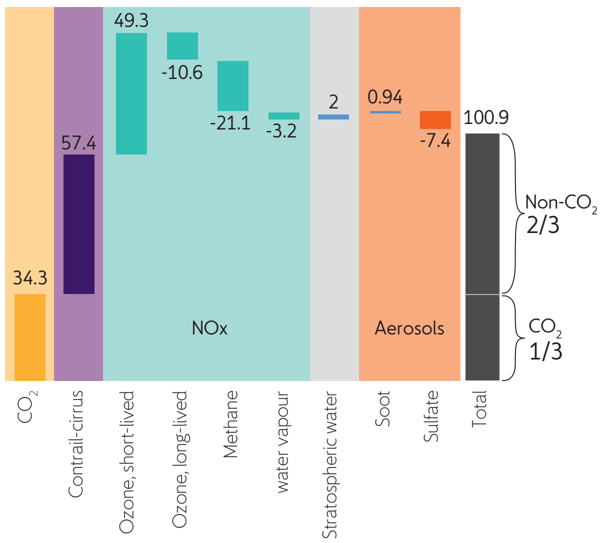


Figure 9: The climate impact of global aviation CO_2 and non-CO_2 effects ((in effective radiative forcing, mW/m2). Based on Lee et al. (2020).

11. Greenhouse gas emissions and environmental impact from aviation infrastructure

Aviation affects both the local and the global environment. In this chapter, we will briefly explain the environmental impact related to aviation infrastructure: greenhouse gas emissions from airport operations and journeys to and from the airport, but also noise pollution from aircraft and helicopters, and emissions to air, water and the ground. Greenhouse gas emissions from air traffic are the subject of the rest of the report.

The status of the local environmental impact are reported regularly in Avinor's Annual and CSR Report.

11.1 GREENHOUSE GAS EMISSIONS FROM AIRPORT OPERATIONS

Avinor's climate goals are fossil-free airport operations in 2030 and to halve GHG emissions by 2022 compared to 2012. Avinor prepares annual climate reports following "The Greenhouse Gas Protocol", and emissions from its own operations are compensated by the purchase of UN-approved climate allowances.

The largest greenhouse gas emissions from Avinor's operation and maintenance of airports derive from fuel consumption by its own vehicles, followed by business travel and energy use.

The greenhouse gas emissions from Avinor's activities depend heavily on weather conditions during the winter season.
An important measure for reducing greenhouse gas emissions from Avinor's own operations is the introduction of advanced biodiesel, as almost half of Avinor's greenhouse gas emissions come from its fleet of vehicles. Advanced biodiesel is used in vehicles that cannot be easily electrified (such as snow removal vehicles). The biodiesel used by Avinor does not contain palm oil or palm oil products, and conforms to the EU's sustainability criteria. When Avinor procures vehicles, an assessment will always be made as to whether a vehicle with an internal combustion engine can be replaced by an electric vehicle. Avinor's first electric 18-metre-long buses were delivered to Oslo Airport in August 2020.

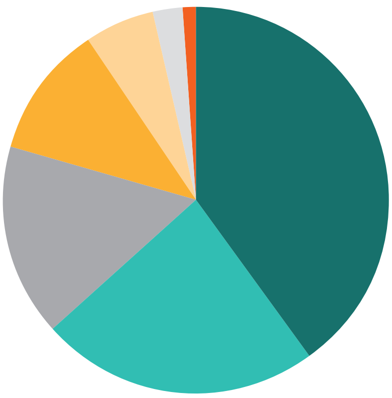


Figure 10: Greenhouse gas emissions from Avinor's own operations in 2019. In line with the usual calculation methods in Norway, Avinor assumes that greenhouse gas emissions from advanced biodiesel/biofuel oil are counted as zero.

The most environmentally-friendly energy is the one that is not used, and therefore Avinor has systematically worked on energy management for several years. Avinor must use renewable energy when possible, as well as using biofuel oil at some airports. Svalbard Airport is particularly challenging due to the current energy supply in Longyearbyen being mainly from coal power. Avinor is working on a number of energy efficiency measures as well as increasing the proportion of renewable energy. Solar cells and wind turbines have been installed at the airport, and Avinor continues to actively contribute to the necessary energy restructuring on Svalbard.

Airport Carbon Accreditation (ACA)[17] is an industry-wide programme to accredit airport operators. Participating airports must set binding targets for reducing greenhouse gas emissions, prepare climate reports and adopt action plans. Avinor's four largest airports are accredited at the highest level of the scheme (Oslo Airport, Bergen Airport, Trondheim Airport and Stavanger Airport), with the addition of Kristiansand Airport at a different level.

11.2 GREENHOUSE GAS EMISSIONS FROM GROUND TRANSPORT TO AND FROM AIRPORTS

In order to strengthen the range of services to passengers, reduce greenhouse gas emissions, and improve the local air quality, Avinor wants to be a driving force and facilitate it so that as many of the journeys to and from the airports as possible can be made using public transport. There are challenges to this related to both the transport network and the modes of transport. Settlement patterns in the airports' catchment area also mean that it is not possible to offer a full range of public transport to everyone. Avinor's largest airports have consistently higher shares of public transport use than other airports in Europe, and Oslo Airport has among the world's highest share of public transport use.

Most measures for increasing the use of public transport fall outside of Avinor's areas of responsibility and require co-operation with a number of other stakeholders. Avinor's most important contribution is facilitating infrastructure at airports, and providing information about services to travellers.

Not everyone can use public transport to travel to the airports. It has therefore been important for Avinor to facilitate the charging of electric vehicles in Avinor's parking areas, so that those who have to

	COLLECTIVE SHARE				
AIRPORT	2009	2018	2019	GOAL 2020	TAXI 2019
Oslo	64	71	72	70	4
Stavanger	14	22	21	30	24
Bergen	27	46	53	50	12
Trondheim	42	45	48	50	13

Table 2. Source: Air passenger surveys (RVU) 2019.

drive can do so with the lowest possible greenhouse gas emissions. This work has been going on since 2014, and almost 1300 charging points have now been established. Avinor is the airport operator in the world with the most charging points available. At several airports, for example at Bergen Airport, charging points/fast charging for taxis has also been implemented.

11.3 OTHER ENVIRONMENTAL IMPACTS FROM AVIATION

Noise pollution from aircraft and helicopters

Under one per cent of Norway's population live in a place where outdoor noise from aircraft and helicopters exceed an average of Lden 55 dB. This mainly includes people exposed to noise from jet fighters, but also those living close to the larger civilian airports in Norway and those with considerable offshore traffic. Since 1999, the number of those being exposed to aircraft noise has been relatively constant despite the strong increase in traffic, mainly due to reduced levels of noise from newer aircraft engines. The most important tool for preventing increased exposure to aircraft noise in residential areas is aircraft noise zone maps that provide long-term predictability by visualising noise footprints. Municipalities are required to use these maps in their area planning.

Over the past 5–6 years, several aircraft operational measures have also been implemented in Norwegian airspace. Measures include the reorganisation of airspace, establishing new procedures for approaches and departures, and the introduction of new technologies. The airspace over Southern Norway has been modernised with a route structure adapted to current traffic patterns. Departures are designed to follow the Noise Abatement Departure Procedure, and continuous descent on approach. The transition from ground-based navigation to the use of satellites (Performance Based Navigation) gives shorter and more direct routes, more energy-efficient approaches and departures, and adapted routes that reduce the noise burden for the airport's neighbours.

Water and soil contamination

There are various requirements that need to be addressed when operating airports, and many of the activities involve use of chemicals. Avinor is continuously working to reduce the overall consumption of chemicals, and subsequently reduce the discharge to the nearby environment, and hence the environmental impact cause by airport operations. This includes striving to find the most environmentally friendly alternatives, and to monitor the discharge and recipients.

According to the Norwegian pollution act, all Avinor aiport must have discharge permits that regulate the amount of e.g. de-icing chemicals and chemicals for fire drills to be used. De-icing chemicals are used to remove ice or snow from the aircrafts prior to departure, to ensure safe flight conditions. Another type of de-icing chemicals are used to provide adequate friction on runways and taxiways to ensure safe landing and take-off conditions.

De-icing chemicals used at Avinor's airports are not toxic, but the decomposition process is oxygen demanding, which can be unfortunate if the natural decomposition capacity of the receiving water is exceeded. Such conditions might be a violation of the discharge permit, and the national environmental authorities can as a consequence require mitigating measures to safeguard the environment.

In order to be adequately prepared for undesirable events and accidents, routine fire drills must be carried out. Such exercises are to be carried out at airports with approved fire training sites as various petroleum products are used in order to create realistic exercises. The fire training sites are connected to run-off systems that include oil separators to protect the natural environment as much as possible.

Until 2011, Avinor used various types of per- and polyfluoroalkyl substances (PFAS) in firefighting foam at their fire training sites. The most known compound, PFOS, was phased out in Avinor in 2001, and was banned in Norway in 2007. Today, Avinor use fluoride-free firefighting foam. However, several years of using fluorinated firefighting foam has led to ground contamination at several of Avinor's fire training sites. These pollutants continue to contribute to the run-off of PFAS to the surrounding area. Avinor has mapped the prevalence of PFAS contaminants, and risk assessments have been made regarding human health and the local ecosystems. Measures are currently being carried out at Oslo, Sogndal and Fagernes Airports. In 2020, Avinor has been instructed to conduct supplementary investigations at several airports, and mitigation measures are expected to be implemented at several of these in the coming years. Avinor is maintaining positive dialogue with the Norwegian Environment Agency regarding these matters.

Air quality

Air quality monitoring is only carried out at Oslo Airport, where measurement results over a number of years have shown that air quality is well within regulatory requirements. The measurement results from Oslo Airport indicate that this is also the case for other Norwegian airports, all of which have significantly less traffic than Oslo Airport. Measurements of ultrafine particles at Oslo Airport have shown low concentrations, and a report from the National Institute of Occupational Health in Norway (STAMI) concluded that emissions connected to diesel exhaust fumes from vehicles, as well as exhaust fumes from parked aircraft, are low and not considerably higher than concentrations in central urban areas[18].

Biodiversity

Many of Avinor's airports are by or are surrounded by areas rich in biodiversity. This includes conservation areas, rare habitats, endangered species, old hayfields, salmon rivers and salmon fjords. For every airport, a field survey of biodiversity was carried out between 2009 and 2013, with the report including management advice. Some of the surveys have since been updated. The guidance is followed to preserve nature as much as possible within the framework of safe and efficient airport operations. The mapping reports are also used for environmental risk analyses, environmental monitoring programmes and in the planning of development and construction activities.

Resources and waste

The airports are working towards a circular approach to resource utilisation and waste. In order to minimise waste and keep the use of resources in the cycle as long as possible, environmental requirements are set for relevant purchases, airports sort waste from their own operations and facilitate sorting on behalf of others, and work is underway for reducing food waste.

12. Emission reduction measures for air travel

There are a number of solutions for reducing greenhouse gas emissions from air traffic. Fleet replacement and efficiency in airspace are measures that have been in place over time and have already resulted in the significant reduction of emissions. Sustainable fuel is certified for aviation and is in the process of being phased in, and a future of aircraft with electric powertrains is realistic. In September 2020, Airbus launched its plans to develop and deploy zero-emissions aircraft by 2035. The plan is to use hydrogen as an energy carrier.

The technologies have different levels of maturity, and they can also have different applications as the operational range is expected to vary:

- In the short term, battery-electric operation will primarily be suitable for relatively short routes with small aircraft. Battery development and any new types of battery may affect this.
- Hybrid solutions and hydrogen are being developed in order to meet the demand for medium distances, and perhaps longer distances in the long term.
- For many years to come, sustainable fuels such as jet biofuel and e-fuels will be necessary for existing aircraft and on long-haul flights.

If the aviation industry is to reach the set targets, several solutions must be put into use. Emissions can be reduced in the short term by using sustainable fuels, while new zero- and low-emission technologies must be developed and phased in concurrently.

This chapter was written to provide an overview based on current knowledge. Much will of course change by 2050, for example the various technologies' realistic reach and relative cost levels. There may also be new technologies that are not currently considered relevant to aviation.

12.1 FLEET RENEWAL

Since passenger aircraft with jet engines were first used in the 1950s, emissions per passenger kilometre has reduced by 80 per cent. Aircraft manufacturers are developing brand new and more energy-efficient aircraft, but are also working to improve existing models in order to reduce fuel consumption and greenhouse gas emissions. The Norwegian airlines continue to work on energy efficiency and the continuous renewal of their fleets. More energy-efficient engines, improved aerodynamics, lower weight and an increased number of seats has contributed to the emissions per passenger kilometre being more than halved over the past 20 years.

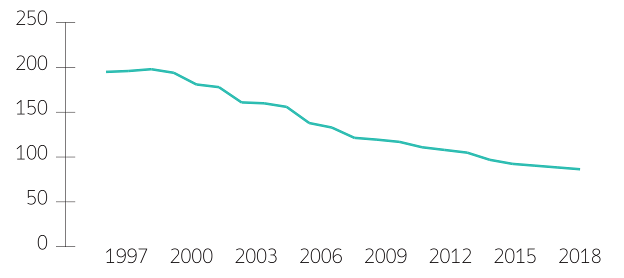


Figure 11: Emissions per passenger kilometre. Average for SAS and Norwegian. Source: The companies' annual reports.

Norwegian

Norwegian's operational fleet consists of Boeing aircraft types 737-800 and 787 Dreamliner, which provide up to 20 per cent lower CO_2 emissions than the aircraft they replace. Fleet renewal is the largest contributor to Norwegian reducing emissions per passenger kilometre by 28 per cent since 2010, corresponding to an annual energy efficiency of 3.6 per cent.

In 2012, Norwegian ordered new aircraft from both Airbus and Boeing. Of this order, Norwegian has so far taken delivery of 22 Boeing 737-800s and 18 737 MAXs, giving nearly 15 per cent lower CO_2 emissions than the 737-800 predecessor. A renewal of all Boeing 737-800 aircraft with either Boeing 737 MAX or Airbus A320neo will further reduce Norwegian's emissions per passenger kilometre.

SAS

SAS has recently invested in new aircraft. This is a fleet entirely consisting of Airbus aircraft: Airbus 350 XWB and A321 LR for long distances, and A320neo for short and medium distances. The aircraft have 13 to 35 per cent lower CO_2 emissions than the planes they are replacing. The transition from Boeing 737-700 and -800 aircraft to new Airbus 320neo aircraft in the Norwegian domestic market started in the autumn of 2020 (Airbus 320neo has been used for flights to and from Norway since 2016). The replacement programme has been accelerated as a result of the coronavirus pandemic, meaning that the new aircraft replacing the B737 in Norway will be fully phased in by 2024.

Since spring 2019, SAS has collaborated with Airbus on the development of low- and zero-emissions aircraft, with a seat capacity of over 100, and which will be particularly suitable for the Scandinavian market. The company has been a contributor to the Airbus ZEROe Programme which was launched in the autumn of 2020.

Widerøe

In 2018, Widerøe started phasing in brand new regional jets (E190-E2). Widerøe was the first airline in the world to use this type of aircraft. The company has phased in three aircraft of this type, and has an option for a further twelve. This type of aircraft has the lowest emissions in the industry compared to other aircraft types of the same size. For example, the fuel consumption is 16 per cent lower than the previous generation, and noise burden is considerably lower than before (more than halved).

Widerøe will renew their short-haul aircraft (Dash 8) in the period up to 2030–2035. The company hopes to become the first in the world to electrify their fleet of aircraft. Electrified aircraft are well suited to Widerøe as they operate on a number of shorter routes with smaller planes. Widerøe is working in partnership with organisations who are in the process of testing electrified solutions, such as Rolls-Royce.

12.2 AIRSPACE EFFICIENCY IMPROVEMENTS

Avinor Air Navigation Services, the airlines and the Norwegian Civil Aviation Authority are continuously working on measures in the airspace that reduce aircraft fuel consumption and greenhouse gas emissions.

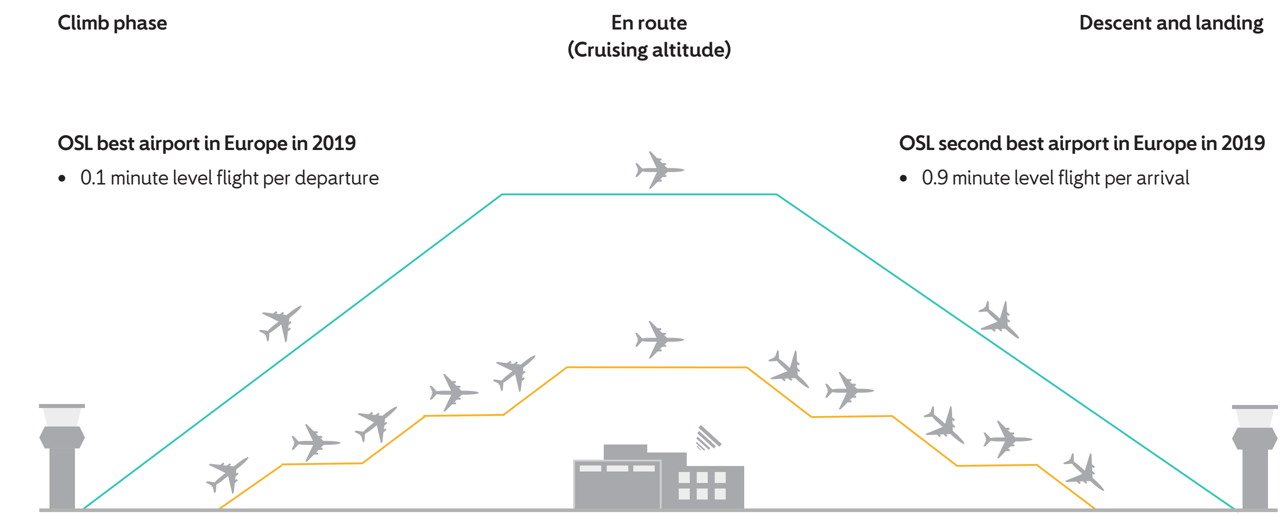


Figure 12: Efficient climb and descent at Oslo Airport. Source: Eurocontrol.[22]

Over the past 5-6 years, the airspace over the whole of Southern Norway has been modernised with a route structure to suit current traffic patterns. Electronic aids for efficient air traffic management and information sharing (Collaborative Decision Making) are important tools and are constantly being developed.

Approach and departures procedures have been designed for continuous climb and descent. The transition from ground-based navigation to the use of satellites (PBN) gives shorter and more direct route guides as well as more energy-efficient approaches and departures.

Norway, Sweden, Denmark, Finland, Latvia and Estonia introduced 'Free Route Airspace' in 2016. This is an airspace organisation that means airlines no longer follow predefined routes, but can fly the most optimal route (trajectories in three dimensions). This reduces both fuel consumption and greenhouse gas emissions.

12.3 SUSTAINABLE FUELS

Biofuel was certified for use in civil aviation in 2009. Since then, several thousand scheduled civilian flights have been carried out where a percentage of biofuel has been blended into the fuel, and the development of various technologies for the production of jet biofuels has accelerated. A major advantage of biofuels is that they can be blended directly into fossil-based aviation fuel and do not require adaptations to either aircraft engines or distribution systems.

SAS has been working on biofuels for aircraft since the year 2000. The first flights in Norway using blended jet biofuel were carried out by SAS and Norwegian in connection with the Zero Conference in November 2014. In January 2016, Avinor Oslo Airport, in collaboration with AirBP, Neste, SkyNRG, Lufthansa Group, KLM and SAS, was the world's first international airport to blend biofuel into the regular fuel supply system and to offer biofuels to all airlines refuelling there. SAS and Widerøe offer their customers the purchase of sustainable biofuels when buying tickets. From 2020, it is a requirement that 0.5 per cent of all aviation fuel sold in Norway must be advanced biofuels (with the exception of the Norwegian Armed Forces). Norway is the first country in the world to introduce such a blending mandate. The Norwegian parliament has adopted a target that 30 per cent of aviation fuel in Norway in 2030 will be advanced biofuel.

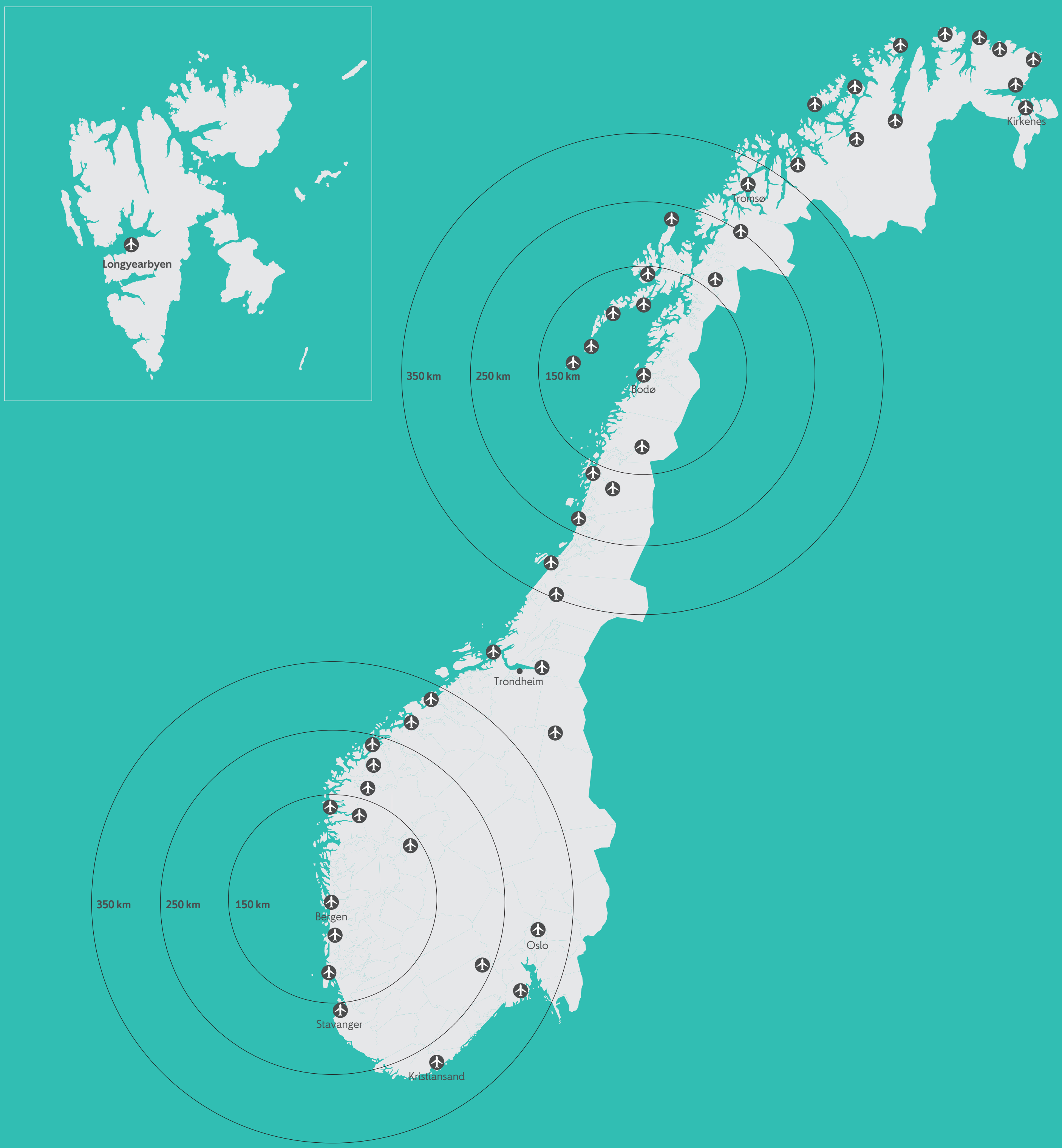
Together with the airlines and NHO Luftfart, Avinor has explored the possibility of establishing large-scale production of biofuels for aviation, based on local biomass. The analyses show that in Norway, it is primarily forestry that will be able to contribute quantities in the size we are talking about in a sustainable way. The conclusion is that waste and byproducts from forestry could provide enough biomass for 30 to 40 per cent of the fuel demand for Norwegian aviation.

Forests will primarily be felled for producing building materials and other high-value products. But leftovers and byproducts could be better utilised. In Norway, we extract less from the forests than what is produced yearly in nature by new forests. The decline of the paper industry in several places has further reduced the processing of forests in Norway and increased exports. A lot of debris is also left in the forest. In this lies both a good opportunity to refine local resources into sustainable fuels, and to create jobs in both the forestry and processing industries.

In the longer term, technology for harvesting, cultivation and processing can change and open up other opportunities. Among other things, marine resources such as algae are pointed to as a resource that can be developed to be of great importance to Norway.

The production of liquid fuels based on raw materials other than biomass

Plans are also being made to produce sustainable fuel from resources other than biomass, e.g. plastic waste. Another example are so-called electrofuels, where with relatively large amounts of electric power, hydrogen is produced via electrolysis, and then the hydrogen is connected to CO_2 in a process resulting in synthetic fuel. Electricity can be sourced either from the electricity grid or by establishing its own production. CO_2 will most likely come from an industrial emission source in the first stage, but can later be obtained directly from the air (Direct Air Capture).



Short distances as the crow flies. Examples of Bergen and Bodø as the starting point.

If synthetic fuels are given greater recognition, and in the long term are considered as advanced fuels in the EU's renewable energy directive, it could lead to a completely different development in the supply of sustainable fuel, as the amount of available biomass no longer needs to define the production cap. One reason why Norway is particularly interesting in this context is the high share of renewable energy in the grid. It is Norwegian aviation's view that e-fuels delivered to aviation must be produced in a sustainable way.

Sustainability and carbon footprint

It is obviously not sustainable when rainforests or other particularly carbon-rich or species-rich vegetation are cut down as biomass for fuel. It is also problematic when the biomass used for fuel could have been used alternatively, such as for food or feed, or if land use is displaced for the production. The Norwegian aviation industry is very clear that the biofuel used at Norwegian airports, both diesel and jet fuel, should meet the EU's sustainability criteria, and that palm oil and palm oil products are unacceptable. The EU's sustainability criteria requires a reduction in greenhouse gas emissions from fossil fuels of at least 60 per cent. Biofuels from byproducts of Norwegian forestry will typically give a significantly greater reduction in emissions (up to 90 per cent).

Most of the biofuel produced in the world today is conventional biofuel (based on agricultural productions), produced for road traffic. In the EU and the EEA, however, measures are in force to ensure that an increasing share are so-called advanced biofuels, i.e. fuel based on waste and residues. Requiring advanced biofuels avoids the challenges of conventional biofuels that conflict with food and feed production and other land use problems. The biomass used will typically be leftovers and byproducts from forestry, agricultural production, household waste and the food industry.

Production and measures

The production of sustainable jet biofuel today in the world is very limited. The Finnish company Neste is the world's largest producer of jet biofuel. There is also ongoing production in California, USA. But there are several facilities planned or under construction in Europe, Asia and the United States. The only production technology that can be said to be fully developed and in commercial use today typically use used cooking oil (UCO) and animal fats as input factors. However, both research and large-scale industrial projects are underway that will increase the maturity of technologies that are suitable for forest residues (which is an important resource in Norway) and household waste.

Many countries and airlines are setting goals to replace an increasing share of today's fossil fuels with jet biofuels. There are also schemes where companies or individual passengers can pay the additional cost of biofuels. Increased demand will lead to increased production.

Production in Norway

At the time of writing, there are several exciting projects in Norway for establishing production of biofuels based on residues and byproducts from forestry. A share of the production could go to aviation.

Two projects that have attracted a lot of attention are Silva Green Fuel and Biozin. Silva Green Fuel will build a plant for the production of bio-oil in Tofte. The facility will be the biggest of its kind in the world. The first phase is the construction of a demo facility, with the goal of a full-scale plant being ready by the end of 2024. Biozin, which has Shell as a technology supplier, is planning to build a full-scale production facility adjacent to Bergene Holm's sawmill in Åmli. The goal is for the production facility to be running by 2025.

It is also worth mentioning Quantafuel, a Norwegian company with proprietary technology for the production of jet biofuel. Avinor has entered into an agreement to pre-purchase biofuel from Quantafuel from a project in which byproducts from the forestry industry will be used.

Projects for the production of e-fuels are also being developed. In Norway in June 2020, Norsk E-fuel presented plans for the construction of a production plant at Herøya. In the first facility, most of the CO_2 will come from an industrial emission source, but it is also planned that a proportion of the CO_2 will be captured from the air (DAC). The plan is to gradually increase the proportion of CO_2 captured from the air in later projects. At the moment, e-fuels do not fall under the blending mandate for advanced biofuels.

None of the technologies to be used in Norway have previously been demonstrated at full scale. Several of the projects have plans for significant expansion if they succeed.

12.4 ELECTRIFIED AIRCRAFT

One of the likely measures for reducing greenhouse gas emissions will be the electrification of every aspect of aviation, including the infrastructure operations such as building and construction, motorised transportation at airports and air traffic itself. Norway is in a unique position to utilise electrified aircraft, thanks to its established market for using smaller aircraft for short flights, considerable interest in the electrification of transport, and almost 100 per cent renewable electricity.

By 'electrified aircraft', we mean aircraft which have one or more electric motors for propulsion in the air. The electricity that drives the motors can come from various sources and we will refer to whether the aircraft are developed as battery-electric, parallel hybrids, serial hybrids or whether they use fuel cells.

The pace of development of electric aircraft has accelerated over the past four to five years. According to the consultancy firm Roland Berger[19], as of January 2020, there were over 200 different initiatives, with varying degrees of maturity, working to develop and realise electric and/or hybrid-electric aircraft for passenger transport[20]. Many of these are fixed-wing aircraft, which in the short term we consider to be of greatest relevance for Norwegian conditions in relation to both range and capacity (number of passengers).

Many small companies and start-ups are establishing a position in the up to 19 seats segment (certified aircraft in accordance with European Union Aviation Saftey Agency (EASA) regulations CS-23), but some of the larger players are also working on development projects in this segment. For larger aircraft, it is the major players, most notably Airbus, Safran and Rolls-Royce who have clearly stated the strategic position that electrification is part of the future, but Boeing, Embraer and all the major engine manufacturers also have ongoing electrification projects.

Airlines have also made their interest known. Widerøe have taken a proactive position, and several American and Northern European airlines (Harbor Air, Logan Air, SAS, EasyJet, among others) have been clear on their wishes and expectations, and also have collaborative projects with aircraft and aircraft engine manufacturers.

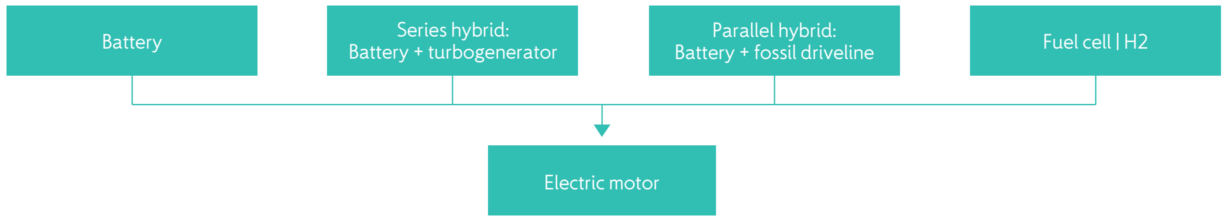


Figure 13: What is an electrified aircraft?

It seems clear that there are no insurmountable technological barriers to the development of electrified aircraft. Based on existing technological knowhow and the expected pace of development, it should be technically possible to develop, certify and introduce regular scheduled civilian flights with up to 19 passengers and a limited range from 2025-2030, and larger aircraft after that.

Battery technology is one of the biggest technological challenges for the rapid development of battery-powered aircraft. Today's dominant battery technology (Lithium-ion) has an energy density of about 250Wh/kg. It is expected that this can be increased to 400-450Wh/kg. Developments are taking place rapidly in this field, and batteries have also become significantly more affordable over the past decade. The next generation of batteries is expected to be 'solid state' batteries, which at present appear to have a maximum capacity in excess of 650Wh/kg. This will have a major impact on the range of electrified aircraft.

Based on the current battery technology and certification standards, up to 19 seats and up to around 350-400km of effective range appear to be the most relevant for first-generation battery-electric aircraft. This is sufficient for many domestic flights within Norway, including most routes on the Norwegian short-haul network.

For longer range, given current known battery technology, it will be necessary to rely on series hybrid solutions, where the aircraft is equipped with not only a battery, but also a "range extender", such as a generator powered by jet biofuel that can charge the batteries as necessary, or parallel hybrid solutions that have both electric and conventional engines.

A third possibility is to use fuel cells. Several players, including Airbus and the start-up ZeroAvia, have been heavily involved here. The use of fuel cells is obviously an exciting solution, not least because one can – provided that the hydrogen is produced with renewable energy – then put zero-emissions solutions in place that also have a considerable range.

There are players in all these segments. It is important to stress that the development of electrified aircraft is still in very early stages, so it is not currently possible to make accurate predictions of timescales or costs. However, "all" aircraft and aircraft engine manufacturers are actively working on electrification. This is an important difference from the automotive industry, where it can be argued that the dominant car manufacturers initially resisted the electrification of road traffic, but have since fully embraced the idea.

There are many projects with different funding and focus that are working on solutions to electrify aircraft. Some examples are given below. A broader presentation is given in the report for the proposal of a programme for the introduction of electrified aircraft in Norway ("Forslag til program for introduksjon av elektrifiserte fly i kommersiell luftfart"). [21]

There is great activity in the market for 2-4 seat aircraft for training purposes (flight school) and other private flights. Slovenian Pipistrel have had a number of projects with both batteries and hydrogen over the past ten years, and have recently had its two-seater Velis Electro model certified. Bye Aerospace in the US is testing eFlyer 2, a two-seater plane, and has a four-seat eFlyer 4 under development. The Norwegian OSM Aviation Group has ordered 60 aircraft to be used in the company's flight school. In this group we also find Norwegian Equator Aircraft, who are developing an electric amphibious aircraft (can land on water and land).

Since 2015, there have been a number of operators involved in the electrified aircraft segment focusing on aircraft with up to 19 seats. The reason why 19 seats is often set as the maximum size is a consequence of the current regulations, where the certification provisions in the EASA CS-23 (Certification Specification) set a limit for two-engine propeller aircraft of 19 seats and 8600kg. If the aircraft is larger than this, it must be certified according to EASA CS-25 Large Aircraft. This imposes different requirements, resulting in a more complex certification process. This segment includes Israeli Eviation and Swedish Heart Aerospace, who are developing battery electric aircraft, American Ampaire and French VoltAero, developing hybrid electric aircraft, and American ZeroAvia who are working on a powertrain for electric engines powered by fuel cells.

It is resource-intensive to develop and certify aircraft. It is therefore especially the major players of the industry who are aiming to develop electrified aircraft with more than 19 seats. Various hybrid electric solutions have been worked on for a long time. One of the world's biggest manufacturers of aircraft engines, Rolls-Royce, have several development programmes for electrified aircraft, and the company's branch in Trondheim is central to this work. Pratt and Whitney and United Technologies are working on Project 804 to develop a parallel hybrid powertrain that has both an electric and conventional engine.

Electrification of aviation also requires new infrastructure at the airports. There are three main approaches to charging: Direct from the grid, via stationary batteries at the airport, or infrastructure for 'swappable batteries', where planes switch to newly charged batteries before flying further. Avinor has promised that electrified small aircraft will receive a landing fee exemption and free electricity until 2025. Furthermore, Avinor has stated that the company takes responsibility for ensuring that adequate charging infrastructure is in place for charging electrified passenger aircraft when needed. It is important to find a sensible corporate and socio-economic approach that also addresses the need for other charging at the airports and in the surrounding area. For example, Avinor and partners are studying through the project Elnett21 in the Stavanger region how smart energy management, energy production, and optimal use of the grid can enable the charging of electric aircraft, ships and buses, without unnecessarily large investments in the existing grid.

12.5 HYDROGEN

Awareness of hydrogen as an energy carrier and the possible use of hydrogen in aviation has been increasing in recent years. Hydrogen can be produced through electrolysis or reforming, for example, natural gas. If the electricity used in electrolysis comes from renewable energy, the production and combustion of hydrogen has no direct greenhouse gas emissions. Hydrogen is a useful energy carrier, and can help to reduce greenhouse gas emissions from aviation in several ways:

- In connection with the production of biofuel (hydrogenation)
- As an input factor in the production of e-fuels
- By direct combustion in custom jet engines
- In a system with fuel cells and electric engines

Furthermore, in the future, hydrogen may play an important role at airports, for example in backup power applications, or as an energy carrier in heavier vehicles.

Hydrogen can be used to produce fuel that can replace today's fossil fuels, and can be used in existing aircraft and infrastructure. Hydrogen is already in use in some contexts today to "enrich" biofuels to satisfy the requirements set for jet biofuels. Furthermore, the term "electrofuels" is derived from the use of hydrogen from electrolysis together with carbon from another source to produce fuel. Both electrofuels/e-fuels and biofuels are discussed in Chapter 12.3.

A more radical application of hydrogen is in a fuel cell or in direct combustion. If hydrogen is used in fuel cells to produce electricity for an electric aircraft motor, it falls within the definition we have used for an "electrified aircraft". Fuel cells are used in private cars in the road sector, and have been used in the aerospace sector. The American start-up ZeroAvia is developing an aircraft powered by fuel cells. It is also possible to burn hydrogen directly in a jet engine. NASA has used this before, and in the 1980s, the Soviet Tupolev tested liquid hydrogen in a TU-155 airliner.

In September 2020, Airbus presented their Airbus ZEROe project, with the goal of having zero-emissions aircraft on the market by 2035, in a concept with hydrogen as the energy carrier. The plans are very ambitious, and it has been signalled that the first test flights will take place as early as 2023. SAS has contributed to the project.

A central premise of hydrogen having an effect on climate change is that it is produced from renewable energy. Norway is well placed for large-scale hydrogen production, and in 2020, the government presented a Norwegian hydrogen strategy and announced that the strategy will be followed up with a roadmap for hydrogen use in Norway. Similar plans are being developed in many other countries, and large resources have been allocated for research and development in this area. Norwegian aviation will closely follow the development of hydrogen as an energy carrier in the time to come, and Avinor will facilitate the supply of hydrogen at its airports as needed.

13. Roadmap to fossil-free aviation

13.1 A ROADMAP FOR NORWEGIAN AVIATION TOWARDS 2050

This roadmap is the result of a joint process between Avinor, Widerøe, SAS, Norwegian, NHO Luftfart and LO. The roadmap plots a course for aviation up to 2050. Norwegian aviation is committed to be a driving force to achieving the objectives of the Paris Agreement.

Under the Paris Agreement, a large majority of the world's countries have committed to putting measures in place to limit global warming to a maximum of 2°C, preferably 1.5°C. In practice, this means that by 2050, the world must be an almost zero-emission society.

Norwegian airlines have already set ambitious targets. This roadmap signals a clear ambition in which Norwegian aviation aims to be a world leader:

Norwegian aviation will be fossil-free by 2050.

This means that from 2050, on flights in and from Norway, fossil fuels will not be used.

This goal is ambitious, and calls for significant investment and changes across the aviation value chain over the next few decades, together with effective measures from the authorities.

A key prerequisite is the continued development of technology and functioning markets for low emission solutions: more energy-efficient aircraft, competitively priced sustainable fuels, solutions for electrification and hydrogen as an energy carrier. This development is already under way, and there is every reason to expect it to continue. Norwegian aviation relies on technology, markets and policies to work together to achieve the fossil-free target in 2050.

Aviation is shaped by strong international competition. Measures and initiatives must be modelled so that they promote the further development of climate-friendly technologies, while not weakening Norwegian airlines' competitive situation. In an industry such as aviation, measures should be first and foremost international and non-discriminatory in nature.

The roadmap will become more tangible over time as it becomes clearer when new technology will be phased in, and when new types of sustainable fuels certified for aviation become available on a larger scale.

Why?

The climate crisis is one of the greatest challenges of our time. All of society – including aviation – must reduce greenhouse gas emissions if irreversible climate change is to be prevented.

Fossil-free aviation will be a very competitive mode of transport and a key contributor to the mobility of the future. Air travel is a superior mode of transport for long distances, and on journeys where time is decisive factor. Air transport plays an important role in business, settlement, exports and tourism, and for Norwegians' mobility in general. Air travel is already characterised by relatively small encroachments on nature and limited noise pollution when compared with other modes of transport.

The cost of reducing emissions in aviation is currently high compared to equivalent costs in other parts of society. Aviation safety takes the highest priority, and there are often long and resource-intensive development and certification processes in the industry. However, in the longer term, low-emission solutions can reduce both costs to the environment and the airlines' operational and maintenance costs. Norwegian aviation believes that it can bring significant advantages to society if targeted measures to phase out fossil fuels are initiated now:

- By taking a leading international role in decarbonising aviation through sustainable fuels and electrification, Norway can make an impact on reducing greenhouse gas emissions far beyond its borders
- Norway has a major competitive advantage for value creation and and industry establishment within sustainable fuels, hydrogen and electrification
- A transition to fossil-free aviation will secure jobs in the aviation, export and tourism industries, and for business in general
- Technological development in aviation takes time; a challenging and ambitious decarbonisation effort requires predictability and a long planning horizon

How?

Technological solutions exist. Sustainable fuels, electrified aircraft and hydrogen will, together with efficiency in airspace and technologies that lower emissions from the fleet, enable fossil-free aviation.

Norway is the first country in the world to implement a blending mandate for sustainable jet biofuels for civil aviation, with effect from 2020. The Norwegian parliament hhas established a target to reach 30 per cent by 2030. Electrification will further reduce the use of fossil fuels, and Avinor and the Norwegian Civil Aviation Authority have prepared a programme proposal for the introduction of electrified aircraft to Norway. A target of fossil-free aviation by 2050 is a confirmation that the industry wants to phase in sustainable fuels and electrified aircraft at an ambitious but realistic pace.

Norwegian aviation will:

- Be a driving force for the development and adoption of zero- and low-emissions solutions
- Phase in sustainable fuels
- Reduce emissions through continued efficiency in airspace, together with optimised planning and operation of flights
- Take the initiative to develop a programme for the production and increased phasing in of sustainable fuels (advanced biofuels and e-fuels)
- Strengthen efforts with communication, incentives and ability for businesses and individual travellers to choose alternatives that are the best for the environment
- Contribute to a good knowledge base on the potential of various low- and zero-emission solutions for the sector
- Regularly report on the achievement of targets, as well as proposing regular benchmarking against other countries where aviation has set ambitious targets (for example, Sweden, Denmark, Finland, the Netherlands and the UK)

Partnership with the government

Norwegian aviation will go to great lengths to achieve the goals set out in this plan, but cannot achieve them alone. In order for Norwegian aviation to contribute to the fulfilment of Norway's climate goals, there needs to be a partnership between the industry and the authorities.

Norwegian aviation proposes:

- The establishment of regular high-level meetings between the authorities and the aviation industry, for example in the form of a dialogue forum, where status, measures and initiatives are discussed with regard to emissions, value creation and the industry's competitive situation
- Significant national and European investment in research and development to bring out competitive technologies that reduce greenhouse gas emissions, including sustainable fuels, electrification and hydrogen
- Predictable framework conditions and secure financing that accelerates the development, production and use of climate-friendly technologies, for example in the form of a fund where taxes the industry currently pay to the state are included
- That Norway works to significantly strengthen international measures at the European and global level, including the EU Emissions Trading System (EU ETS) and the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA).
- That measures that can enable the early introduction of electrified aircraft in line with the "Proposal of a programme for the introduction of electric aircraft in commercial aviation" are phased in
- That the public sector uses its purchasing power to create demand for sustainable fuels
- A transformation to fossil-free aviation that can create jobs throughout Norway; in order to realise the potential for value creation in Norway, there is a need for the government to strengthen the facilitation for the establishment and scaling of Norwegian industry

13.2 MILESTONES TOWARDS 2050

By 2030

As sustainable fuels can be used directly in today's fleet of aircraft, this is a solution that can be phased in without investing in new aircraft. In order to be successful with large-scale phasing in of sustainable fuels, it will also be important to have sustainable production in place on a large scale (jet biofuels and e-fuels).

It is also important to put in place a framework as soon as possible for large-scale phasing in of fossil-free solutions for aviation; this is needed to relieve the additional costs of increasing the phasing in of sustainable fuels; for electrification and phasing in of other new technologies, certainty is needed about the framework conditions in order to encourage investment in new technologies.

Based on information from players who will deliver aircraft and associated solutions, it is realistic that the first electrified planes that can go into scheduled traffic will be in place well before 2030.

The companies' goals:

2025

- SAS: Reduce total CO_2 emissions by 25 per cent compared to 2005

2030

- SAS: Halving total CO_2 emissions compared to 2005, if framework conditions are in place. Phasing in of sustainable fuel equivalent to the fuel consumption of all of SAS' domestic flights within Scandinavia.
- Norwegian: Reduce CO_2 emissions per passenger kilometre by 45 per cent compared to 2010 through both fleet renewal and use of sustainable fuels. The airline is committing to use between 16 and 28 per cent sustainable fuel by the end of the decade, depending on the proportion of the fleet being renewed. The target is up to 500 million litres of sustainable fuel used annually by 2030.
- Widerøe: The company is also making use of sustainable fuel, but the biggest emission reductions will come when the short-haul fleet is electrified in the period up to 2030-2035
- Avinor: Airport operations fossil-free by 2030

SAS, Norwegian and Widerøe have signalled increasing demand for sustainable fuels towards 2030, and are interested in entering into an active dialogue with suppliers. Avinor, NHO Luftfart and LO also want to contribute to Norwegian production of sustainable fuel for aviation. Norwegian aviation represents a significant demand that could form the basis for increased production of sustainable fuel in Norway.

Towards 2040

2040 is too far in the future for the airlines to give specific plans about their fleets.

The signals from technology development experts and relevant suppliers are that the first electrified aircraft for passenger traffic will be able to be delivered well before 2030, and that it may be possible to have introduced zero-emissions aircraft on a large scale by 2040. Widerøe's ambition is for the short-haul network to be electrified well before 2040. This is also supported by extensive efforts from Airbus to be able to deliver zero-emissions aircraft with hydrogen as an energy carrier by 2035. Avinor takes responsibility for relevant infrastructure for new technological solutions to be in place at the airports.

13.3 MORE DETAIL ON THE ROADMAP

What do we mean by fossil-free aviation?

By fossil-free, we mean that only non-fossil fuels should be used. This means that the propulsion of aircraft is powered by sustainable fuel, electricity or hydrogen, and implies the following preconditions:

- That sustainable biofuels are considered emission-free (in line with current practice)
- That emissions from the production of aircraft and the construction of infrastructure are not included in the calculation
- That electricity in Norway's power grid is considered fossil-free

The Paris Agreement

Under the Paris Agreement, a large majority of the world's countries have committed to putting measures in place to limit global warming to a maximum of 2°C, preferably 1.5°C. In practice, this means that by 2050, the world must be an almost zero-emission society.

Under the Paris Agreement, Norway has committed itself, together with the EU, to reducing emissions by at least 40 per cent by 2030. Furthermore, it has been decided that by 2050, Norway will be a low-emissions society, with greenhouse gas emissions down by 80 to 95 per cent compared with 1990. These goals are regulated by the Climate Change Act[23]. The goals are already ambitious, and society seems to be moving towards strengthened goals. For example, Norway is working to strengthen the common goal within the EU to at least 50, preferably 55, per cent reduction by 2030, and the EU Commission has proposed a target of 55 per cent. The most important general measures in Norway are the EU Emission Trading System allowances for the sector and the national CO_2 tax.

International cooperation and framework conditions

Norwegian airlines are exposed to tough international competition. Norwegian aviation will not be able to achieve the goal of being fossil-free by 2050 if the rest of the world takes a different direction. However, it must be assumed that the vast majority of the world's countries will follow up on the commitments of the Paris Agreement so that international agreements will eventually become more binding and individual countries will follow policies providing drastic reductions in the use of fossil fuels for all sectors.

An international example

Norway has taken a leading position internationally in many thematic areas when it comes to creating an early market for low- and zero-emissions technologies. Some examples are electric cars and ferries. Norwegian aviation has been an early pioneer in the implementation of new solutions, and Norway is also well positioned to take a leading role in the phasing in of low- and zero-emissions solutions for aviation.

Oslo Airport was the world's first international airport to blend jet biofuel into the ordinary fuel system, and to offer this to all airlines that refuel there. And Norway was the first country in the world with a blending mandate for jet biofuels.

Many developers look to Norway for demonstration and testing of electrified aircraft. A very high share of renewable energy in the power mix, and many short routes with few passengers make Norway an attractive market. The Norwegian Civil Aviation Authority has entered into an agreement with the European Union Aviation Safety Agency (EASA) to accelerate the process of the phasing in of electric airliners. The agreement covers technology services, legislation and other facilitation[24].

A high share of renewable energy in the power network also gives Norway a good basis for the production of green hydrogen.

The Norwegian aviation industry believes that Norway can lead the way internationally by being early adopters of low and zero-emissions solutions for aviation, thereby contributing to reducing global greenhouse gas emissions.

Value creation in Norway

Closely linked to goals to be an international example, there are good opportunities for Norwegian business and industry.

A transition to electrified flights requires major investments, both on the ground and in the air. There are good grounds for the pioneering of this type of technology in Norway. There are already concrete plans for establishing the production of e-fuels in Norway.

With regards to biofuels, it can be pointed out that there is considerable potential with byproducts and waste products from Norwegian forests, and in the longer term from algae and other marine resources. There are good opportunities for jobs in several places in the value chain: the forest industries, marine industries and the process industry.

Aviation wants to contribute to Norwegian value creation. Fuel produced in Norway provides better control of both the supply situation and the climate impact/sustainability.

In order to achieve the goal of value creation in Norway, Norwegian aviation recommends that the authorities strengthen the facilitation for the establishing of Norwegian industry. There is a need for input from Enova, Innovation Norway, and others.

Creating a market

Framework conditions are obviously important. But other measures can also be taken to create a market for low- and zero-emissions solutions in aviation. For example, the public sector can contribute by paying for the additional cost of alternative fuel on their business trips. The state can also work in international forums to ensure that airports can provide advantages to airlines that emit less per passenger kilometre per passenger kilometre, or that use low or zero-emission solutions. Norwegian aviation will do its part, and actively work with communication, incentives, and choices so that passengers and companies are given the opportunity and are encouraged to contribute to lower emissions through various measures (for example by paying for the additional cost of alternative fuels).

Knowledge base, benchmarking and further dialogue

A good factual basis is crucial for continually assessing whether the industry is on track to achieve its goals. The publication of this report is an initiative from the aviation industry to establish a good common factual basis. This work will be continued and strengthened. Aviation will contribute to a good factual basis about potential and sustainability in the various low- and zero-emissions solutions for the sector, and ongoing reporting on the achievement of goals. Aviation will also conduct ongoing benchmarking against other countries where aviation has set ambitious goals (for example, Sweden, Denmark, Finland, the Netherlands and the UK). Norwegian aviation envisages that this factual basis will be used in a dialogue with the authorities on the achievement of goals and framework conditions.

The document will be followed up with more specific plans on individual elements that are central to achieving the goal. The strategy will become clearer and more concrete over time, as it becomes clearer when new technologies will be able to be phased in, and when new types of fuels certified for aviation will be available on a large scale. Good measures will also contribute to increased clarity on the pace of the restructuring.

14. Forecast for traffic and emissions

The forecasts for emissions in this chapter are based on the traffic projections from Chapter 9. In line with historical data and international forecasts, 1.5 per cent annual energy efficiency is assumed. The development of aircraft, engines, the transition to larger aircraft and the higher cabin factors contribute to increased energy efficiency. [From a historical perspective, the 1.5 per cent annual improvement in energy efficiency can be said to be a conservative estimate.]

With an expected traffic growth of 0.7 per cent domestically, emissions from domestic aviation are expected to decline in the future. The emissions from international air travel are expected to continue rising by about 1 per cent each year (with annual traffic growth expected to be 2.5 per cent). This is before the effect of new non-fossil fuel types and energy carriers are taken into account.

The forecasts do not include helicopter traffic, which has not been represented in the process in the same way as regular scheduled air traffic.

The forecasts are based on reference forecasts from The Institute of Transport Economics for air passengers towards 2040, divided into three segments: domestic, Europe and intercontinental flights. Within each segment, it is assumed that the average flight distance does not change over time.

The road to 2050

Based on the forecasts and projections of energy efficiency already presented, as well as the ambitions set out in the roadmap, Figure 15 shows a possible trajectory for the phasing in of non-fossil fuels in aviation up to 2050.

The goal is fossil-free aviation by 2050. Sustainable fuels are already being put into use in line with blending mandates and the ambitions of the airlines. Electrification and hydrogen will come eventually. It is not exact calculations that form the basis of the figure, but approximate expectations for when different technologies will be phased in.

In September 2020, the Air Transport Action Group (ATAG), the industry's interest organisation for climate and social responsibility, published a report[25] looking at how international aviation can meet emission reduction targets set for society. This is a global analysis; some regions and countries have set more ambitious targets. The report from ATAG presents four scenarios with differing priorities and technological development paths for meeting the goal. These scenarios illustrate how there may be several paths towards 2050; this is the case both internationally and for Norwegian aviation. The pace of phasing in of various technologies will depend on framework conditions, market conditions, the development of technology, etc.

Domestically, the three airlines that have been involved with the report and the roadmap are completely dominant. For international travel, the conditions are different; many international airlines operate in Norwegian airports. It is the three Norwegian airlines who are behind the report and the roadmap, but the goal must be that the framework conditions are designed so that all airlines flying from Norwegian airports contribute to achieving the goals of the roadmaps.

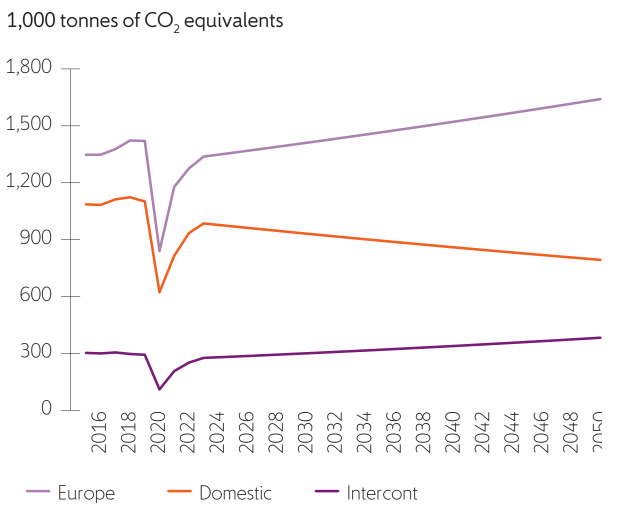


Figure 14: Emissions from Norwegian aviation 2016-2050, with expected traffic growth and efficiency. Without expected phasing in of sustainable fuels, electrification and hydrogen.

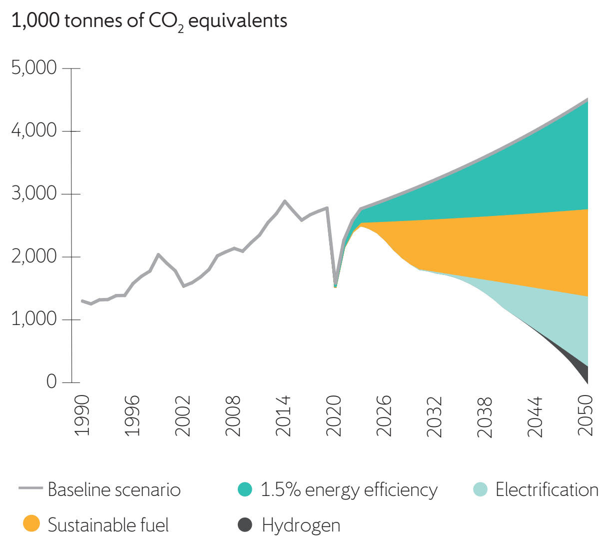


Figure 15: The road towards 2050.

Endnotes

1 "E-fuels" is short for electrofuels, which are a type of synthetic fuel produced with large amounts of electric power.

2 https://www.eurocontrol.int/publication/fuel-tankering-european-skies-economic-benefits-and-environmental-impact

3 Institute of Transport Economics report 1321/2014.

4 Asplan Viak 2020, Climate impact from passenger travel by air, train and car; supplementary report to Avinor's sustainability report 2020.

5 Statistics Norway 2020, Table 11823: Euro classes, fuel types and vehicle groups (K) 2016 – 2019.

6 A. Nordelöf et. al. "Environmental impacts of hybrid, plug-in hybrid, and battery electric vehicles – what can we learn from life cycle assessment?" 2014.

7 Statistics Norway 2020, Table 10484: Passenger transport by rail, by train route 2012–2019.

8 Calculated from Table 08510: Air transport. Passengers between Norwegian airports 2009K1 – 2020K2, and Table 08512: Air transport. Aircraft movements and seats between Norwegian airports 2009K1 – 2020K2.

9 Some exemptions have been granted for the allowance requirement for a number of Public Service Obligation (PSO) routes, military flights, flights for the emergency services, craft under 5700kg, and commercial operators with emissions of less that 10,000 tonnes per year or with fewer than 243 flights in three consecutive four month periods. For more exemptions, see § 1-2 and § 1-2a in allowances the Regulations on reducing quotas and trade with quotas for greenhouse gas emissions (the Greenhouse Gas Emissions Regulations)..

10 https://www.iata.org/en/iata-repository/publications/economic-reports/Five-years-to-return-to-the-pre-pandemic-level-of-passenger-demand/

11 Avinor states how many passengers the airports – be they arriving, departing or transferring between flights (counted as a transfer both on arrival and on departure). The total number is called "terminal passengers". The figure for Norway in 2019 was 56 million terminal passengers, of which 2 million were at private airports and 54 million at Avinor airports.

12 Note that Statistics Norway has adopted a new model for calculating greenhouse gas emissions from aviation, and that the figures stated differ somewhat from previous years.

13 Source: IATA (https://www.iata.org/en/iata-repository/publications/economic-reports/airline-industry-economic-performance---december-2019---report/)

14 Lee, D. S., et al. (2020). "The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018." *Atmospheric Environment*, 117834.

15 Radiative forcing is the energy imbalance in the Earth system since pre-industrial times, measured in Watts per square metre. ERF additionally accounts for the rapid atmospheric adjustments following an initial perturbation.

16 Through the Research Council Norway funded collaboration project AVIATE (Aviation in a low carbon society) led by CICERO (https://cicero.oslo.no/no/aviate_home). Avinor and SAS are partners in the project.

17 For more inforamtion about the ACA, see https://airportco2.org/ and https://www.airportcarbonaccreditation.org/

18 https://stami.brage.unit.no/stami-xmlui/bitstream/handle/11250/284998/Diesel%20Sluttrapport.pdf?sequence=1&isAllowed=y

19 https://www.rolandberger.com/en/Point-of-View/Electric-propulsion-is-finally-on-the-map.html

20 https://www.rolandberger.com/en/Point-of-View/Electric-propulsion-is-finally-on-the-map.html

21 https://kommunikasjon.ntb.no/pressemelding/norge-skal-vaere-hovedarena-for-elektrifisering-av-luftfart?publisherId=17421123&releaseId=17880960

22 https://www.eurocontrol.int/sites/default/files/2020-06/eurocontrol-prr-2019.pdf

23 https://lovdata.no/dokument/NL/lov/2017-06-16-60

24 https://luftfartstilsynet.no/om-oss/nyheter/nyheter-2019/norge-blir-europeisk-satsingsomrade/

25 https://aviationbenefits.org/environmental-efficiency/climate-action/waypoint-2050/

Work on the report was initiated and led by Avinor and carried out in partnership with Norwegian, SAS, Widerøe, Norwegian Confederation of Trade Unions (LO) and the Federation of Norwegian Aviation Industries (NHO Luftfart). The steering group consisted of the following:

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